A PRACTICAL

TREATISE ON PETROLEUM.

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TREATISE ON PETROLEUM:

COMPRISING

ITS ORIGIN, GEOLOGY, GEOGRAPHICAL DISTRIBUTION, HISTORY, CHEMISTRY, MINING, TECHNOLOGY, USES AND TRANSPORTATION.

TOGETHER WITH A

DESCRIPTION OF GAS WELLS, THE APPLICATION OF GAS AS FUEL, ETC.

BY

BENJAMIN J. CREW.

WITH AN APPENDIX

ON THE

PRODUCT AND EXHAUSTION OF THE OIL REGIONS AND THE GEOLOGY OF NATURAL GAS IN PENNSYLVANIA AND NEW YORK.
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PREFACE.

THE Author of this treatise, Mr. Benjamin J. Crew, died on the fifth of November, 1885, just as he was on the point of completing his manuscript, leaving little else to be done except to supply the illustrations. This untoward event has caused a delay in the publication of the book, and rendered necessary the addition to it of the more recent history and statistics of both American and Russian petroleum and of natural gas, together with the newest applications of these products. In this important work, and in carrying the volume through the press, the publishers beg here to acknowledge their indebtedness to the brother of the author, Mr. J. Lewis Crew, who has been intimately connected with the petroleum industry since 1862, to Mr. Frank W. Edwards, Superintendent of the Chester Oil Co., Thurlow, Pa., to Mr. William T. Brannt, who has contributed considerable matter from the German, as well as to Dr. Wm. H. Wahl and to Mr. Charles A. Ashburner, the latter Geologist in Charge, Second Geological Survey of Pennsylvania, who has contributed an important paper on petroleum, as well as one on natural gas, both of which will be found in the Appendix.

Had the author lived he would doubtless have taken pleasure in here specially acknowledging his indebtedness to the publications of the Second Geological Survey of Pennsylvania, and particularly to the contributions to them of Mr. John F. Carll, who

has made himself a high authority on the geology of the oil regions, and to Professor Peckham, the author of the United States Census Report 1880, on Petroleum and its Products; as also to Mr. Charles Marvin, the author of 'The Regions of the Eternal Fire,' and of other publications illustrative of the history and condition of the Russian petroleum region of the Caspian.

In conclusion, it only needs to be said that Mr. Benjamin J. Crew, the author of this volume, was connected with the business of refining petroleum from almost the earliest day in the history of the American product, and that up to the close of his valuable and exemplary life he retained a lively interest in the subject; and it is believed that he has made a valuable contribution to the technology of the important industry of which he has here treated.

H. C. B.

PHILADELPHIA, December 29, 1886.

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A PRACTICAL TREATISE ON PETROLEUM.

CHAPTER I.

THE ORIGIN OF PETROLEUM.

IT may readily be supposed that as long as questions concerning the geological relations of petroleum remain unanswered, equally perplexing difficulties will attend the solution of the problem of its origin. If it were positively ascertained, for example, that vast deposits of organic remains had been formed at a certain geological period; if it could be clearly shown that at another period of time such deposits had been subjected to destructive distillation; if the track of the distillate could be traced from its parent bed to the porous sandstone reservoir—if conditions like these could be clearly shown to have existed, we could approach the subject of the origin of petroleum with reasonable hope of arriving at a satisfactory conclusion. But in the present stage of the controversy, when any one of the above-mentioned conditions, which at present appear to be essential to its formation, is controverted, we are

placed at a great disadvantage in entering upon the discussion of any theory. Indeed, so grave are the difficulties and objections which beset the path of any theory that our best geologists, while leaning at times, it may be, to one or the other of the various solutions which have been offered in explanation, confessedly prefer to wait for more light upon a matter literally so hidden and obscure. Professor Lesley, the State Geologist of Pennsylvania, says: "The origin of petroleum is still an unsolved problem. That it is in some way connected with the vastly abundant accumulations of palæozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group, scarcely admits of dispute; but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds, is utterly unknown. That it ascended into them rather than descended seems indicated by the fact that the lowest sands hold oil when those above do not, and that the upper sands hold oil when they extend beyond or overhang the lower."

An opinion at one time extensively prevailed among certain oil prospectors, that petroleum was in some way associated as a product with the bituminous coal measures. Some have supposed that it was a resultant of distillation of this variety of coal, others that it was "the natural drainage" of the coal beds; both classes were equally ignorant and careless as to whether the oil ascended or descended after

its formation. As might be expected, wells drilled upon hopes so illusory and baseless failed to respond to the projector's expectations. The oil-bearing sands lie many thousand feet beneath the lowest of the coal strata, and no well ever drilled in that section has pierced them. The opinion, however, was not an unreasonable one in view of the ignorance then existing among all classes as to the true sources of the oil, and, in the absence of correct information respecting the geology of that section of country. It was an acknowledged fact that an oil almost identical in appearance and chemical composition had been artificially produced by the distillation of certain bituminous shales. Why could not Nature in her vast subterranean laboratory produce a corresponding product from bituminous coal? The existence of marsh-gas, the fire-damp of the mines, and a constant associate of petroleum belonging chemically to the same paraffine series of hydrocarbons, as petroleum, seemed also to point to an identity of origin. Two considerations, however, have satisfied both the oil miner and the scientist that bituminous coal is not the real source of the petroleum of commerce. The miner has been satisfied because he can find no oil anywhere near the coal beds, and the geologist has been satisfied because he has a more correct knowledge of its origin and formation. We, therefore, hear very little at the present time about petroleum being either the product of distillation from the coal beds, or of its being "the natural drainage" therefrom.

Lesquereaux has furnished some interesting views on

this subject. He is of the opinion "that petroleum is the result of the decomposition of *marine* plants, as coal is the result of terrestrial vegetation. The conclusion is natural, for there exists an evident correlation between the formation of both kinds of deposits of bitumen.

"There is no doubt that the marine vegetation of the palæozoic ages can be compared for luxuriance, and in some measure for its composition also, to the terrestrial vegetation of the coal epoch. From the upper Devonian down to the lower Silurian, some strata of shales are not only covered, but, indeed, filled sometimes for hundreds of feet in thickness with fossilized forms of hydrophytes." As illustrating the extent of such deposits "the great bank of *Sargassum*, which extends between the 20th and 45th parallels of latitude, covers, according to Humboldt's computation, a space of more than 260,000 square miles. In places the floating bank is so thick as to arrest the progress of vessels, and it appears at present to be of the same extent and to occupy the same place as when it was first noticed by navigators. What can we then infer to have been the result of a vegetation whose force was at least double what it is now, and which has written its history in whole strata of great thickness? . . . Thus also the remains of marine plants in the shales of the Devonian point out, I think, not only the fecundity of an ancient marine vegetation but its result in the contemporaneous deposit of petroleum.

"The Chlorosperm of the palæozoic times with their simple bladdery conformation and their green color were

undoubtedly prepared to perform in the water the same function as the coal plants performed in the atmosphere. As the result of terrestrial vegetation has been first woody tissue, and then, by its decomposition, coal; so the result of marine vegetation has been first cellular tissue filled with a kind of liquid carbon; and, as the carbon is unalterable, the decomposition of the plant has left it free as fluid bitumen or petroleum. . . . . The geographical distribution of petroleum and that of the remains of marine algæ present the same remarkable coincidence. At Oil Creek, Slippery Rock Creek, in the Chemung of Virginia, Ohio, Kentucky, everywhere indeed where oil has been seen, either in cavities or saturating the rocks, and where the strata are open to view, a remarkable amount of fucoidal remains has been seen. This cannot be a mere casual coincidence."

The author appends to this paper the following note: "Professor Liebig, to whom I wrote a *résumé* of my opinion on this subject with the request that he would point out to me the result of chemical analyses of marine plants, if there were any either in support or discredit of my idea, kindly answered that there were unhappily no analyses of species of fucus or other hydrophytes which could be used as affording a support to my views, but that my arguments, based on exact researches, were so conclusive that, for himself at least, they had removed any doubts of the truth of the theory."[1]

[1] Lesquereaux, Transactions American Philosophical Society, vol. xiii. 1869, pp. 313–328.

The theory of the origin of petroleum held by Prof. J. S. Newberry is briefly as follows: It is well known that in the growth of plants, the mysterious principle called life produces the dissociation of the elements composing carbonic acid and water breaking the strongest bonds of inorganic chemistry. Under this influence, structures of hundreds of feet in height, and many tons in weight, are piled up in antagonism to the force of gravitation and the affinities of inorganic chemistry. When the life spark leaves this structure, and its creative and conservative power is no longer exerted, the mass stands as an unstable compound, and the oxygen which has been divorced from its carbon by the intrusive life force now hastens to reclaim its own. This reunion may take place slowly and quietly, and is then named "decay," but under favoring circumstances, with heat and fury, which is called combustion. The result in each case is the same; the organic tissue is oxidized; the affinities of inorganic chemistry reassert themselves; the stable compounds carbonic acid and water are formed and pass away; hydrocarbons are evolved and oxidized, and, in place of the great mass of organic tissue, a handful of ashes is left, which represents the mineral matter, woven by life into its ephemeral fabric. This process of the decomposition of organic matter may be hastened or retarded, but it can hardly be permanently arrested. By excluding oxygen and applying heat, the constituents of the mass react upon themselves, forming new compounds, solids, liquids, and gases, several of which possess properties which make them useful to man during

their existence, or in the development of usable force in the act of passing to their inevitable destiny, oxidation.

The chemical composition of wood tissue varies somewhat in different kinds of wood, but a typical example chosen by Bischof, gave:—

Carbon	49.1
Hydrogen	6.3
Oxygen	44.6
	100.0

When this is placed in a retort and subjected to destructive distillation, there are evolved from it watery vapor, acetic acid, condensable vapors of naphtha, and, as the heat is increased, uncondensable gases, such as carburetted hydrogen, water from the combination of hydrogen and oxygen, and carbonic acid—the latter from a combination of the carbon and oxygen. The ultimate residual is charcoal (consisting of carbon) and the ash of the plant, in all perhaps one-quarter of the original mass. A similar round of changes may take place spontaneously, and at a low temperature. When buried under water or under wet earth, vegetable tissue is still slowly oxidized, since water absorbs some air; but apart from this, the original tissue is greatly modified by the reaction of its constituents upon themselves. The carbon, hydrogen, and oxygen combine in part to form carbonic acid gas, water, carburetted hydrogen, naphtha (petroleum), which escape in part, remaining temporarily as a solid residuum, which becomes at first brown, and ultimately black from its free carbon, and is known first as lignite, and subsequently, as

it progressively changes, as coal, anthracite, etc. The escape of gases from vegetable matter decaying in shallow water has been seen by almost every one. The solution of liquid hydrocarbons has also been observed, and would be more frequently noticed if carefully looked for. The process of subterranean or subaqueous distillation of vegetable tissue is called bituminization, because one of its temporary products is bitumen, which saturates or invests the residual carbon, giving it a pitchy appearance. This process goes on as long as there is any organic compound left in the mass; the final residuum is graphite, the intermediate stages being represented by peat, lignite, bituminous coal, anthracite, etc. Some of its phenomena may be observed in the evolution of carburetted hydrogen, and carbonic acid (under the names of "fire-damp" and "choke-damp"), from beds of lignite and coal, and by a constant flow of inflammable gas and petroleum from strata of bituminous shale. The spontaneous distillation and oxidation of the organic constituents of beds of lignite, coal, and carbonaceous shale may be seen along their lines of outcrop, even when the carbon of the most exposed portions is altogether burnt off, leaving an ash or clay behind. As the strata are penetrated, the percentage of carbon and hydrogen constantly increases, until, having passed beyond the seat of atmospheric influences, the mass is found presenting its natural physical and chemical characters.

It would not be proper to take leave of this branch of the subject without bringing to the notice of our readers the only remaining theory regarding the origin of petro-

leum, which is deserving of attention at our hands. We do this in justice to the distinguished chemist, whose views on all questions relating to his profession are entitled to eminent respect and careful consideration. We have discussed as briefly as its importance would permit, the vegetable and animal origin of petroleum, and will here call attention to—

Berthelot's Theory of its Mineral Origin.

This is best stated in Mr. Berthelot's own words as set forth in a paper published in the 'Ann. de Chim. et de Phys.,' vol. ix. page 482, 1866.

"The hypothesis recently put forth by M. Daubrée, that the terrestrial mass contains free alkali metals in its interior, joined to the experiments which I have lately made, leads almost necessarily to a mode of explaining the formation of hydrocarbons. In fact, according to my experiments, the carbonic acid everywhere infiltrated into the crust of the earth coming in contact with alkali metals forms acetylides. These same acetylides would result also from the contact of earthy carbonates with alkali metals even below a dull-red heat. Now these alkaline acetylides once formed may be subjected to the action of steam, and free acetylene would be the result, if the product were immediately withdrawn from the influence of heat, hydrogen, and other matters present. But on account of the conditions being different, the acetylene would not exist, as my recent experiments prove. In its place we obtain either products of condensation, which approach the

bitumen and tars, or the products of the reaction of hydrogen upon the matters already condensed, that is to say, hydrocarbons more hydrogenated. For example, the hydrogen reacting upon the acetylene produces ethylene and hydride of ethylene. A new reaction of the hydrogen either upon the polymerides of the acetylene, or upon those of the ethylene, *would give rise to saturated hydrocarbons such as constitute American petroleum.* An almost unlimited diversity in the reaction is here possible according to the temperature and the bodies present. We can thus conceive the production by a purely mineral method of all the natural hydrocarbons by the intervention of heat, water, and alkali metals. Lastly, the tendency of the hydrocarbons to unite together so as to form more condensed matter, suffices to account for the formation of these curious compounds. This formation can also be effected in a continuous manner, since the reactions which produce it are incessantly renewed."

This beautiful and ingenious theory has more in it to commend itself to the chemist than to the geologist. The latter would find the conditions required by M. Berthelot to be absolutely wanting in the strata in which petroleum is found. The alkali metals or their carbonates are not present in or anywhere near the oil-sands. As metals they would exist as primitive material, and we must go far below these to find the conditions necessary for the formation of petroleum according to this theory. As at present advised, therefore, we must rest our case in looking upon this product as having either an animal or vegetable

origin, or both combined. That there are difficulties attendant upon any theory we must admit, but these are being laid aside one by one as new light dawns upon us.

While, therefore, geologists are generally consenting to the opinion that petroleum is the product of a slow destructive distillation of organic remains, the point of interest, and perhaps we may say, the point of divergence in sentiment is the unsolved question whether the strata in which the oil is now found are to be regarded as the parent rocks, or whether (as for instance the oil-bearing sand-rocks) they are to be considered as the reservoirs into which the distilled product has found a permanent lodgement. Both of these views have their distinguished advocates, and it cannot be denied that an array of facts may be cited to prove or disprove either one or the other of these controverted positions. In the end it will probably be found to be the case, that certain geological strata in which oil is found already formed, really form its starting point and resting place, and that certain other strata are simply receptacles for oil formed in other beds.

Upon an examination of the fragments of the oil-bearing sand-rock brought to the surface during the operation of drilling, we are unable to detect in them anything which points to such a process of destructive distillation as we have described. There is no *débris*, no residuary product. Could it be possible—is it within the bounds of sound inductive reasoning—that such vast quantities of organic matter as would be necessary to form a supply of oil

such as is found in these rocks, could have so wholly disappeared as to leave no vestige of their existence?

Again, it might be asked, if these sand strata were the original places of deposit for this organic matter, at what period of their formation was this material thrown there? If placed upon the ocean beach before its subsidence below the water level, the essential conditions for destructive distillation, and the formation of these hydrocarbons are wanting. There would be, it is true, an evaporation of the watery constituents of their structure, and a residuary product of their mineral elements, but under no circumstances such as we are now considering could there have been formed a single trace of oil. It is equally fallacious to conjecture the elimination of oil from such a bed of material, which had been recently placed by its subsidence below the ocean; here, again, the conditions necessary for the formation of oil are wanting; but, granting the possibility, what would be the destination of oil so formed? Certainly it would not be to remain in the position where it was generated.

It would undoubtedly obey the laws of gravity, and, being specifically lighter than water surrounding it, it would rise to the surface and be either wafted to some place of deposit, or be dissipated by evaporation and disappear altogether.

In order to meet the conditions necessary for the formation of oil, we must therefore allow of the subsidence of this deposit (protected also from dissipation and waste by a previous covering of sand) to such a depth as where the

internal fires of the earth could perform their function of the operation. Now, while admitting this possibly reasonable supposition, we are confronted with the fact that there are to be found within the same district no less than six successive deposits of similar formation, each of which in its turn would have to be lowered to the oil-making horizon. Mr. Carll places " the vertical distance between the third oil-sand (the Venango 3d) and Mahoning sandstone at 1550 feet. Therefore when the Mahoning sandstone occupied the plane of spontaneous distillation, the third oil-sand must have been 1550 feet below it, and subject by reason of this additional depth to a degree of heat much greater than that of the horizon in which the oil contained in it was formed." With this theory in view, we must suppose that the lowest in the series of these formations would have to be subjected to a higher degree of heat than either of the others and for a vastly longer period of time. The effect of this lengthened exposure upon the lowest oil-bearing rock would be to drive off by the ordinary process of distillation the lighter and more volatile hydrocarbons, and we should expect to find the heaviest variety of petroleum. On the contrary, we find just the reverse of this, and it is the uniform experience that the lightest oils are found in the lowest sandstones, while the heaviest oils are drawn from the shallowest wells; and, as we approach the surface where it is gathered from pools dug to the depth of only a few feet, it becomes viscid, semi-fluid, and finally a solid asphalt.

As far, then, as we are able to form an opinion upon this

subject, from the data at present at our command, we conclude that the sand-rocks of the oil region of Western Pennsylvania are merely reservoirs for the collection and reception of the oil which has been formed from bituminous shales lying beneath the sand.

The question is an important one, not only from a scientific point of view, but also in an economic light. Having located the stratum according to a correct theory, very large amounts, now uselessly wasted in drilling for oil, might be saved.

The Sand Strata as Reservoirs.

Upon the assumption that the sand-rocks are not the parent rocks in which the petroleum was originally formed, but are merely receptacles for its reception after its formation, an interesting question is that which relates to the capacity of these strata for holding such immense volumes of oil as have already been removed and as they appear still to contain. It was doubted by many that they were the reservoirs, because it appeared impossible that a sandstone apparently so homogeneous in its structure could hold such vast quantities of oil. These assumed the necessity of large subterranean fissures or cavities. That fissures are occasionally met with in drilling wells, is a well-known fact; but that they are of such dimensions as to fulfil the required indications, we have no proof whatever, and the truth is, that the facts of the case are altogether opposed to any such theory. In the early days of oil mining, to strike

a fissure in the oil-sand and have the drilling tools perhaps drop into a small pool of oil, was considered an essential indication of a paying well. The fact, however, which has been abundantly demonstrated, that large wells have been obtained without penetrating any such fissure, has long since discredited any such theory. Indeed, the largest and most profitable wells have been drilled in those sands which are the most homogeneous in their structure, and where a fissure would be difficult to find. We do not mean that it should be inferred from what has been said, that there are not fissures in the sand-rocks, and, sometimes, even fissures of considerable dimensions. Crevices of various dimensions are to be met with in the whole course of operation of drilling a well. Sometimes these give considerable annoyance to the well-digger and throw his hole "out of plumb." Instances have also occurred where two or more wells have pierced the same fissure, thus interfering with each other; but instances of this kind are rare, and do not by any means prove that fissures are essential to a paying well. It is also a fact beyond dispute that crevices of the kind we are speaking of are more frequent in the first and second sands than in the deeper third sand, which is found also to contain salt water and oil, while the first sand generally contains fresh water. It is evident that all these strata must have been thoroughly saturated with salt water. The upper ones from their situation, which is suitable for drainage and percolation from surface water, have been altered in this respect.

In reverting, however, to the subject of the capacity of

these sand strata to contain oil, I avail myself of the superior knowledge of Mr. John F. Carll on the subject, who has made some interesting calculations and actual experiments calculated to throw much light on it. In this connection he says:—

"If we examine a piece of oil-rock brought up after a torpedo has been exploded, or some of the third sandstone taken by the hand from the stratum and laid open to view at the bottom of the large oil shaft sunk by blasting at Tidioute, we shall find it simply a conglomerate of pebbles seldom larger than grains of wheat loosely held together in a sandy matrix. At first sight it hardly seems possible for any large quantity of oil to pass into a well through the interstices between the pebbles, but experiments made in a crude way on a number of pieces of this oil-rock prove quite conclusively that it is capable of absorbing and holding from one-fifteenth to one-tenth of its own bulk of water or oil; this too when the pores of the rock are more or less clogged with residuum from the oil previously held by it, and without its being charged under pressure.

"The diameter of an ordinary oil well being $5\frac{1}{2}$ inches, the circumference of the circle is therefore $17\frac{28}{100}$ inches, and the area of its cross section $23\frac{76}{100}$ square inches. Suppose the interspaces of the oil-rock to amount in proportion to its whole bulk to only one-seventeenth instead of one-fifteenth or one-tenth, as we have ascertained it to be in some cases, then, for every inch of depth drilled in an oil-sand by which $17\frac{28}{100}$ square inches of its surface are laid bare (saying nothing about the bottom area of the

hole), we shall at least have one square inch of oil ducts venting into the well. A depth then of $23\frac{76}{100}$ inches would give $23\frac{76}{100}$ square inches as the combined area of the inflowing oil leads, and this equals the full capacity of the $5\frac{1}{2}$ inch hole. In other words, the aggregate sum of the pores or interstices of a sand rock of this kind as exposed to the walls of a well of $5\frac{1}{2}$ inches diameter is equivalent to the area of an open crevice, one inch wide, extending from top to bottom of the gravel bed, whatever its thickness may be. No account is here made of the friction encountered by the oil in passing through the thousands of pores in the sandstone, nor of the compensating force of gas impelling the oil under a tremendous pressure through them. This imperfect calculation is not intended to show just how much oil a porous rock could deliver, but simply to exhibit the possibilities of a flow through and from it, *equal ever to the full capacity of the well bore.* When there are five to ten feet of this kind of rock to drill through, it can readily be seen that a flow of three or four thousand barrels per day might easily be maintained through the operation of these numerous oil-leads, making ample allowance for friction and all other contingencies, without requiring the *aid of crevices to convey the oil into the well.*"

In further confirmation of his opinion respecting the capacity of the sand rocks for holding oil, he appends a few figures, which will afford the means of readily calculating the possible capacity of a porous sandstone; and any one who will take the trouble to study and apply

them, will perceive that "lakes of oil" may be stored in a sandstone 30, 50, or 100 feet in thickness, without the intervention of extensive caverns or fissures.

Superficial Quantities.

43,500	square feet in an acre.
27,878,400	" " in a square mile.
4,014,489,000	" inches in a square mile.

Cubical Quantities.

9702	cubic inches in a barrel of 42 gallons.
5.6	" feet " " "

Production of Oil per Acre.

646.53	barrels,	if the	sheet of	oil be 1	inch deep.
1293.06	"	"	"	2	inches deep.
1939.59	"	"	"	3	"
4997.68	"	"	"	7¾	"

Production of Oil per Square Mile.

414,779.65	barrels,	if the	sheet of	oil be 1	inch deep.
829,559.30	"	"	"	2	inches deep.
1,244,338.95	"	"	"	3	"
3,198,515.20	"	"	"	7¾	"

We have said before that experiments made in a crude way indicate that an oil sand may contain as much as one-tenth of its bulk in oil. There can be little doubt that a good rock, in its normal condition and under pressure, might hold an equivalent of one-eighth. This would be equal to a solid sheet of oil one and a half inches in thickness in any vertical foot of good oil sand, or nearly 1000 barrels per acre. On Oil Creek there are generally 30 to 50 feet of third sand, and also from 15

to 30 feet of stray sand, both locally producing oil. Of this total, suppose only 15 feet are good oil-bearing pebble, we shall then have a producing capacity of 15,000 barrels per acre, or 9,600,000 barrels per square mile, which is adequate to the requirements of the most exceptional cases known.

CHAPTER II.

GEOLOGY OF PETROLEUM.

Upon a subject concerning which the most learned and industrious scientists of the present day have conscientiously differed, it does not become a non-professional writer to dogmatize. We, therefore, approach this portion of our work, viz., the description of the geological occurrence of petroleum, with the simple end in view of placing before our readers, in the plainest manner possible, a *résumé* of the views now held by those most competent to pass judgment on this subject.

Among American geologists, as far as I am aware, the opinion prevails generally, that the petroleum of commerce is of organic origin; also, that it is a product of the destructive distillation of organic remains, which were deposited in certain geological strata; that these subsequently, by subsidence, fell below the ocean level, and were covered by deposits obtained from corrosions of the rocky coast line, through the agency of water, and that, by repeated upheavals and sinkings, numerous layers or strata were superimposed; and that those deposits of organized structures, whether animal or vegetable, were subjected by the internal heat of the earth to a decomposing temperature, resulting in the formation of petro-

leum, which found a lodgement and reservoir among the porous sand rocks, where it is now found. While, in the opinion of a number of geologists, the bulk of the oil has a vegetable origin, there appears abundant evidence to show that a portion proceeds from the decomposition of animal remains. Perhaps no subject has afforded a wider or more interesting field for geological investigation than this. Hypotheses have been abundant, and the track of the search is strewn with the wrecks of such speculations, but amidst all this, sound scientific views (the result of much exploration, diligent research, and the systematic classification of recorded observations) have been slowly evolved; which, while they greatly simplify the subject, serve to harmonize many theories formerly apparently discordant, and also many facts, which at one time seemed at variance with each other. It is safe to say, that eight-tenths of all the petroleum produced at present on this continent comes from a narrow belt of territory, about twenty miles in width, lying parallel with and about fifty miles west of the Allegheny Mountains, stretching from the southern part of New York State, passing through Pennsylvania, Western Virginia, Kentucky, and reaching into the northern part of Tennessee. All parts of this territory are by no means equally rich in oil. The productive spots, however, lie within its limits, but appear to have no connection with each other, although probably belonging to the same geological period. Miles of unproductive territory lie between these, in which the most industrious prospectors have failed to find oil, except in

small quantities. The most productive fields yet discovered lie within the boundaries of the two States, New York and Pennsylvania. The natural course of the rivers of the United States clearly points to the existence of a great valley, lying between the Allegheny Mountains on the east and the Rocky Mountains on the west, having its greatest depression in the bed of the Mississippi River, which drains this great valley through its numerous tributaries. From the nature of the strata found throughout this region, we may reasonably suppose that, in the far distant past, a great ocean here rolled its waters, the Allegheny Mountains forming its eastern coast line, while the Rocky Mountains defined its western limit. The western base of the Allegheny Mountains became the natural place of deposit of immense beds of both vegetable and animal remains; which form the starting point for the production of our present supply of oil. These deposits lie very far down, even below the coal formation, and belong chiefly to the Devonian age. It is asserted, however, that petroleum occurs in stratified rocks of all ages, from the Laurentian (said to be the oldest rock in which organic remains have been found) to the quite recent tertiary period. The rocks in which this process of destructive distillation is supposed to have had its origin, are denominated shales. The reservoirs of the product of this distillation constitute the productive sand rocks, so often alluded to in the oil districts, in which it has been stored. These porous sand beds, in which the Pennsylvania oil is found, belong chiefly to the Chemung group

of the Devonian formation. Of the shales spoken of above, there are several well-known varieties.

Professor Alexander Winchell, in his 'Sketches of Creation,' presents the following synopsis of these different shales, which, in his opinion, furnish the oil supply of this region:—

"I. The black shales of the Cincinnati group afford oil which accumulates in the fissured shaly limestones of the same group and supplies the Burkesville region of Southern Kentucky and Manitoulin Island, in Lake Huron.

"II. The Marcellus shale affords most of the petroleum which accumulates in the fissured shaly limestones of the Hamilton group, and thus supplies the Ontario oil region, locally divided into the Bothwell district, the Oil Springs district, and the Petrolea district. The Marcellus shale also affords a large portion of the oil which accumulates in the drift gravel of the Ontario region.

"III. The Genesee shale, with perhaps some contributions from the Marcellus shale, affords oil which accumulates in cavities and fissures within itself in some of the Glasgow regions of Southern Kentucky. It affords also the oil which accumulates in the sandstones of the Portage and Chemung groups in Northwestern Pennsylvania and contiguous parts of Ohio. It affords also the oil which accumulates in the sandstones of the Waverly (Marshall) group in Central Ohio. It affords also that which accumulates in the mountain limestone of the Glasgow region of Kentucky and contiguous parts of Tennessee, and also

some of that which is found in the drift gravel of the Ontario region.

"IV. The shaly coals of the false coal measures, aided perhaps by the Genesee and Marcellus shales, seem to afford the oil which assembles in the coal conglomerate as worked in Southwestern Pennsylvania, West Virginia, Southern Ohio, and the contiguous, but comparatively barren region, of Paint Creek, in Kentucky.

"From this exhibit it appears that the principal supplies of petroleum, east of the Rocky Mountains, have been generated in four different formations, accumulated in nine different formations, and worked in nine different districts."[1]

With regard to the manner in which the different sand rocks, which, particularly in Western Pennsylvania, constitute the chief reservoirs of petroleum, are formed, there is still a controversy. As to the precise nature of the forces, which directed their deposition and marked out their depth of thickness and their respective areas, it may be said that the opinion of geologists is still in the formative stage. In a matter of so much importance and amid such a contrariety of sentiment, it is a positive relief to refer to the opinions of so able a geologist as Mr. John F. Carll, connected with the Second Geological Survey of Pennsylvania, to whom has been assigned the examination of the oil-bearing strata of Western Pennsylvania. In connection with this subject, with the modesty of the true scientist, Mr. Carll says:—

[1] Professor Winchell's 'Sketches of Creation,' page 292 *et seq.*

"The mountains rise above us, but who can write an indisputable history of the precise manner of their construction? The oil sands spread out beneath our feet; who can go. down into the dark places of the deep, or back into the unknown ages of the abysmal past, and gather the facts for a special and detailed account of their deposition, which shall carry the conviction of truthfulness to all who may read it? The manner in which these oil sands were deposited is one of these measurably uncertain problems. Many strange and fanciful theories have been advanced to account for their presence in the position where they have been found. They have been supposed by some to have been ejected through a portion of the superstrata by subterranean force operating beneath them. They have been described, and by reputable geologists too, on the one hand, as fractured anticlinal arches, on the other, as synclinal troughs traversed by fissures and crevices containing salt-water, oil, and gas. They have been pictured as long sand-cores, cast in grooves a few yards wide and running as straight as an arrow for miles, as if some huge grooving-machine had passed over the bed rocks of shale in a northeast-southwest direction, making an uniform furrow a few rods wide and thirty feet or more in depth in the centre, which was, in some unaccountable manner, filled in at a later day with coarse sand and gravel." Mr. Carll does not stop to refute these baseless theories and speculations, but proceeds to examine, "1st, what dynamical agents were employed in the construction or building up of these rocks; 2d, what was the

character of the materials used in the formative process; and 3d, with such forces and such materials what would be the probable structure of the rocks, judging from what we see under analogous circumstances at the present time?"

The space which we have appropriated to this branch of our subject will not permit us to present his views regarding this formation, but that these sand rocks are of sedimentary origin seems to us beyond dispute. Sedimentary rocks are defined by the geologist Lyell to be those which "are formed from materials thrown down from a state of suspension or solution in water." The materials comprising these may vary greatly in relative coarseness or fineness. In one position, boulders, such as "paving-stones," may have been hurled by the violence of a rushing current and deposited in one place; stones of a smaller size are carried further, and find a resting place quite beyond the limit of the former; while gravel and sand of varying fineness are carried still further, and deposited at a distance from the others, exactly proportionate to the size and weight of the particles composing the drift. The conclusion, then, is irresistible, if these sand strata are sedimentary they could only have been placed in their present positions by currents of oceans, lakes, or rivers. There appears to be no other force now in operation on the face of the earth, except the eroding and buoyant forces of water in rapid motion, sufficient to explain the observed phenomena. The materials composing the different sand rocks are laid bare by the operations of the "drill," and also by the inspec-

tion of the outcropping layers of the same deposit in some contiguous section. "They vary from coarse conglomerates, containing quartz pebbles, occasionally two inches in diameter, through all grades of conglomerates, down to pebble sand, sandstone, sandy shale, slate, and the most finely levigated mud rock or 'soap-stone,' of the driller." The great irregularity and apparent disorder noticed in the distribution of these patches of sand rock may thus be accounted for when we take in connection with this the fact that these forces are varying continually in energy, "affected by winds and tides and storms, affected by changes of levels intensifying their powers at one time in this place, at another time in that. The oil sands are frequently massive conglomerates, made up of the coarsest materials to be found in the formation to which they belong. The conclusion is unavoidable, therefore, that they owe their origin to the action of the strongest depositing currents prevailing at the period of their deposition." It is also a reasonable deduction, that these deposits were made near the coast line, and were subsequently submerged by the subsidence of the land over which the ocean rolled. That there were many alternations of the level of the ocean and the land, occasioned by the subsidence just alluded to, or by the uprising of mountain ranges, is a fact too plainly written on the stone leaves of the "book of Nature" to be questioned. As we come to turn over these leaves we find that Nature has there recorded also—the day's work.

These oil sands, lying within the district before men-

tioned, have been accurately mapped out, and their relative distances from the surface carefully measured. They appear to have a well-defined relation to certain well-known geological formations, cropping out in certain locations. Mr. Carll states: "The relative geological position of the several oil-bearing horizons may be ascertained approximately by measuring down from the base of the bottom member of the carboniferous series. The Olean conglomerate, a persistent and well-defined stratum, seen on the high places in all these districts, is a convenient and reliable datum to calculate from. Starting, therefore, at the Olean conglomerate, at the depth of 450 feet, we have the first sandstone, unproductive here; at the depth of 800 feet we have the Venango group of oil sand; between this and N. Warren oil horizon, at the depth of 1100 feet, we have unproductive shales; at 1300 feet we have the Warren third sandstone; at 1450 feet we have the Clarendon third sandstone; at about the same depth we have the Bradford slush oil; at 1625 feet we have the Cherry Grove third sandstone; at 1850 feet we have the Cooper or Forrest Company third sandstone; at about the same depth we have the prolific third sandstone of the Bradford district; and at the depth of 1900 feet we have the Allegheny sand rock." At the present time the Bradford district is producing most of the oil found within the limits of this belt. It has been estimated that there are now about twelve thousand producing wells within an area of one hundred and fifty square miles. The productive spots have been pretty well defined by the line of

"dry holes" which surround them. It is entirely beyond the skill of even the professional geologist to define, in a certain district, the area of these producing sands, with the data before him, to which we have before adverted. Taking into consideration the dip of the strata, he can tell accurately the depth to which the drill must go to pierce the oil horizon, but to foretell that the particular formation he is in search of will be found in that particular locality, is beyond his ability; and if it is not there, what has caused its removal is equally beyond his knowledge. These productive spots evidently belong to the same horizon, and are geologically of the same age. They appear to have been formed under precisely the same conditions, and yet they have no connection whatever with each other, and between them, at times, there are miles of unproductive territory. A great deal of capital and labor are vainly spent in prospecting for oil by those who ignore the intelligent deductions of science in a matter of this kind. Many, in their blind search for oil, insist that these sand strata must necessarily be continuous, because the geologist cannot exactly define the reason why they are not so. In a contest of opinion the drill must decide. There are those again who "ignore all consideration of age of rocks on stratigraphy, and make no distinction between the oil-producing sand belonging to the carboniferous formations at Dunkard's Creek and those of the Lower Chemung at Warren or Bradford."

The author is indebted, also, for some valuable matter in connection with these different sand rocks, to Mr. Charles

A. Ashburner (connected with the Second Geological Survey of Pennsylvania), who has made several valuable contributions to our knowledge of the geology of petroleum. This gentleman has clearly shown, for instance, that the third sandstone of the Bradford district is a wholly distinct formation from the third sandstone of the Venango, and that these two strata have no connection with each other, and must have been formed under entirely different circumstances, and perhaps at remotely connected periods of time. He states that the Bradford sandstone consists of a gray and white sand, of about the same coarseness as the ordinary beach-sand of the Jersey coast, compact, yet loosely cemented. The average thickness of the sand is about forty-five feet, and from top to bottom the sandy strata change but little in their general character. It is only when specimens from the successive layers are placed side by side and closely examined that any difference in structure can be recognized. The grains of sand are angular, vary but slightly in size, color, and the quantity of cementing material, which holds them together in the rock bed.

The same homogeneousness, which characterizes the vertical section is found to exist over a considerable horizontal area. In fact but little change is found to exist in the sand obtained from wells fifteen miles apart or in the sand from the immediate wells. The area of the Bradford district is about one hundred and ten square miles. In this area the sand is so regular and constant that if wells were drilled at random the number of dry holes which

would be obtained would hardly exceed two in every hundred, and even this percentage is based upon wells which were drilled outside of the probable oil country and were genuine "wild-cat wells." Based on lithological and stratigraphical facts, he makes the Venango oil-sand group the equivalent of the Red Catskill No. IX. (Old Red Sandstone), while the Bradford sand is of Chemung age. A productive sand consists of a white, gray, or yellow pebble rock, the pebbles being loosely cemented together and generally imbedded in firm sand. The rock is open and porous. The interstices between the pebbles and sand grains are extensive and capable of containing a large bulk of oil, but this character does not maintain itself over any extended area. The Venango sands are not homogeneous over any considerable area. The thickness of the sand varies, and is subject to sudden changes in character and productiveness in very short distances.

The difference in the structure of the sands when considered in connection with their relative productiveness is a strong argument in support of the view which has been accepted by the best informed of our geologists that sands are only reservoirs or sponges which serve to hold the oil coming almost entirely from a lower formation in which it has originated. The Venango sands, he supposes to be shore or shallow-water deposits, while the Bradford sand was possibly deposited in deeper water by a slower and more even current, and was probably formed in a bay or estuary. Mr. Carll, to whom we have already referred, has also published the fact that the Bradford producing sand

was probably one thousand feet below the Venango third sand, and facts since obtained show this to have been a close estimate. It would thus appear that while the Bradford sand rock has been placed in its present position through the operation of the same forces which located the Venango sand, these forces were modified in degree and were in action at a period of time anterior to the formation of the Venango group.

The oil produced in the Bradford district, as might be supposed from the homogeneousness of its source, is remarkably uniform in its gravity and quality. It has generally also been found to be the case, that the deeper the sand rock the lighter the gravity of the oil, whereas as it approaches the surface of the earth it becomes more dense in consistency, varying in this respect from an oil of 28° Baumé to one of 50°.

While it would appear from the foregoing representations that the sand rocks in which the oil is now chiefly found are not the parent rocks, it may not be out of place here to notice the existence of other formations in which it might be reasonable to suppose that the oil had found both its birthplace and resting spot. It has long been a popular error to suppose that the coal beds of Pennsylvania were the real source of supply of our oil. The holders of such opinions appear either to have been ignorant or regardless of the fact, that the oil-bearing strata plunge far below the coal beds and were deposited in their ocean bed long before the forest growth, which gave rise to the coal formation, had made its appearance. It has also been found

that the coal measures which ought to have been more thoroughly saturated with oil (if this view were correct) are far less so than formations of a more ancient date.

Prospectors for oil have often been greatly imposed upon by what are termed "surface indications." There is no allusion here to those "indications of oil" which are the direct result of fraud and deceit, where attempts have been made to dispose of valuable (!) oil territory which had been treated to a "top-dressing" with the natural crude oil from a well in a contiguous district, or where it had been, with the same fraudulent intent, thrown into a well, hoping thus to find a speedy purchaser. Nature's most valuable stores are often most deeply hidden, and it has been found that the most capacious reservoirs of petroleum are not found near the surface liable to waste, but lie at considerable depths below the surface, and make no display of their hidden wealth. A certain variety of limestone formation, known as Corniferous Limestone, has had great attractions for oil prospectors; it appears in some localities to be rich in bituminous products, smelling strongly of petroleum. According to Professor Winchell it has beguiled many to the brink of financial ruin, as oil in paying quantities has never been produced from it. From many indications it would seem that it was a parent rock, and that the oil found in it had its birth there. This formation "is extensively distributed throughout the West, and has afforded a wide field for the display of credulity that could not believe the truth, and avarice that could not spend enough in a bootless enterprise. It stretches in

a broad belt from Columbus, in Ohio, northward to near the State line, where it bifurcates, one belt trending Northwestward across Northern Indiana and into Southwestern Michigan, passing under Lake Michigan and crossing eastward, so as to reappear in the northern part of the State and form the headlands about Mackinac. The other belt trends northeastward passing into Southeastern Michigan beneath the western end of Lake Erie, and reappearing in the neighborhood of Woodstock and London in Ontario, whence it deflects to the northwest and passes under the middle of Lake Huron, reappearing in the headlands and islands of Michigan some distance southeast of Mackinac. Throughout nearly this whole extent it has been riddled by borers for oil, but to this day no productive and paying well has ever been opened in this formation."

Dr. T. Sterry Hunt in his report (*vide* the Geological Survey of Canada, 1866, page 241) states that the Corniferous Limestone of the lower Devonian is the source of the oil of the western peninsula of Canada, and underlies a large portion of this territory, and that several flowing oil wells have been found in this formation in Eastern Kentucky, one of these was in Estell County, where the auger penetrated a large fissure into which it dropped. This was followed by a flow of salt water, succeeded by a stream of oil. This apparent discrepancy between these authorities may, possibly, sooner or later be reconciled.

Several conditions appear to be necessary in the formation of productive oil territory. Of course there must have

been deposited, perhaps upon some ocean beach in the ages long rolled past, a vast amount of organic remains either vegetable or animal. If these had remained uncovered or unprotected, a slow disappearance of their organic constituents would have occurred, in which case there could not possibly have been any oil formed. Thus it became necessary to cover these remains with deposits of sand. Now in order to subject them to the necessary heat for destructive distillation, it supposes this stratum should be deeply covered with successive depositions, by which covering the internal heat of the earth is prevented from being dissipated in its revolutions through space. Having thus our materials gathered for the process, and having placed our rocky retort in position, Nature liberally, yet in her own time (for her working days are centuries), supplies the heat necessary. But if there is to be a product of this distillation, there must be provided a receiver commensurate in size into which it may be stored. We have this already formed in the overlying porous sandstones, which are so many immense reservoirs covering hundreds of square miles of territory. These formations must in turn be protected by a rocky impervious covering to prevent the escape of the oil in an upward direction and to complete these grand subterranean "oil works," and to prevent the escape of the product in a lateral direction, and its wasteful dissemination generally. This impervious covering should so conform to the adjacent strata, that the oil formed and stored in the sand should be effectually sealed up. From a number of observations made in the drilling of wells in

the oil regions, it appears that the absence of either of the above-mentioned conditions renders what appears to be the most " satisfactory showing" illusory and disappointing.

The oil thus stored in the " sand formation may be equally disseminated through its porous structure, or it may find a lodgement in a fissure or cavity of enormous dimensions. The fact has been frequently noticed that upon reaching the oil sand, the tools have suddenly dropped, and volumes of oil have been immediately thrown out of the well.

" The escape of the oil at the surface of a well is caused sometimes by mere hydrostatic pressure as water rises in common artesian wells. More frequently perhaps the oil is forced up by the elastic reaction of confined gases. An open cavity or a porous portion of rock bounded on all sides by impervious walls which constitutes a virtual cavity may be partly filled with oil, while gases occupy the higher portions of the cavity. Such a cavity whether actual or virtual may possess any form or extent, or may consist of a number of cavities connected by narrow passages or mere fissures. In nearly all cases more or less gas accompanies the oil and subsists under a very high degree of pressure. The pressure in such cases is not the hydrostatic pressure of water, but a consequence of the continued generation of gas and oil, long after the cavity has been filled. If a boring happens to penetrate the higher portion of such a cavity the gas at once rushes forth with greater or less violence and persistence. As soon, however, as the tension is relieved the

escape ceases. No oil will be obtained without applying suction, since there is no hydrostatic pressure exerted from behind, and the secretion of the gas tends rather to confine the oil in the lowest ramifications of the cavity.

"Suppose, however, on boring a hole for oil we happen to penetrate some of the lower portions of the cavity occupied by the oil. The elastic pressure of the confined gas will at once force the oil up and produce a spouting or blowing well. The flow must necessarily subside by degrees as the confined gas, by the escape of the oil, acquires more space for its accommodation. It may continue, however, until the cavity is exhausted of its oil, after which pumping will be of no avail. If the confined gas attains its equilibrium before the oil has been completely forced from the cavity, it is evident that the remainder must be obtained by pumping. There is no cavity so large, however, as not to be destined to ultimate exhaustion. Every oil-well of whatever class is destined to abandonment. It is true that nature is constantly at work replenishing the exhausted reservoirs, but her accumulations are slow.

"Intermittent wells appear to act in some cases precisely after the manner of intermittent springs. More frequently, however, it is manifest that the combined action of gas and oil produces the phenomenon. In boring a well suppose a stream of gas is struck one hundred feet from the surface of the rock and a small stream of oil twenty feet below the gas, the entrance of oil fills twenty feet of the hole and begins to submerge the fissure at which

the gas is escaping; the gas forces its way through the oil with a sputtering sound, bubble after bubble rising to the surface. As the oil ascends the gas makes louder and louder complaints till finally summoning all its accumulated energies it hoists the superincumbent column of oil to the surface and pours it out in a stream of a few seconds' duration. The flow then ceases and the same operation begins to be repeated. After a minute or more of renewed grumbling and sputtering the pent-up gas again relieves itself, and thus the work continues. The same results would ensue if oil and gas found entrance at the same fissure, or even if the gas were admitted at any distance beneath the entrance of a small supply of oil."[1]

The pressure exerted either upon bodies of oil or water by the expansive force of gas thus confined is enormous; when we add to this the additional pressure of a column of water of a thousand or more feet in height, we may form a very slight, but a wholly inadequate idea of the force with which a stream of gas is thrown from an opening into such a cavity. In many instances the roaring as of a tornado may be heard for many miles. We shall have occasion elsewhere to speak of some of the phenomena associated with wells of this character.

[1] Winchell. 'Sketches of Creation,' p. 284.

CHAPTER III.

GEOGRAPHICAL DISTRIBUTION OF PETROLEUM.

PETROLEUM, under the various synonyms of rock-oil, mineral oil, naphtha, bitumen, pitch, asphaltum, mineral wax, has been known and employed for thousands of years. The earliest mention we have of it, is the Biblical record of its use by the patriarch Noah, who rendered the Ark impervious to the "floods of waters" by giving his vessel two coats of "pitch," "within and without." Combining, as we shall discover further on, with its water-proof qualities, the property of preserving timber from decay to a remarkable degree, it may be safely said that no better substitute for similar purposes has yet been discovered. That it was in general use, and for a variety of purposes, very early in the history of man, there can be little doubt. We learn a little further on in the sacred volume, that the generation immediately following commenced on the plains of Shinar "to build a tower whose top may reach unto heaven." In the construction of this edifice they "used brick for stone and *slime* had they for mortar." The mortar employed in this building was one of the many forms of this bituminous substance, which, on account of its peculiar viscid, adhesive, and indestructible qualities, was admirably adapted for a building of such

pretentious proportions. During the recent excavations amid the ruins of the ancient cities of Nineveh and Babylon, abundant evidence was found to show that the same kind of cement was used. Even as an illuminating material in the first century of the Christian era, under the name of "Sicilian oil," we learn of its employment through the learned medical writer, Dioscorides. From a variety of other sources, too numerous to mention, we learn that prodigal Nature has placed within easy reach of man this abundant source of light and heat, whose real value we have only within comparatively recent years begun to appreciate. As found upon the earth's surface, it varies in consistency from a solid homogeneous mass to a thin oily liquid. In color it assumes every shade from a "jet" black to a nearly colorless fluid. (The material from which the highly polished "jet" ornaments are made is but one of the forms of this substance.) Its odor is peculiar, disagreeable, persistent. As it comes from the wells it is generally by reflected light of a dark green hue, while by transmitted light it has a deep red color. The characteristic iridescent appearance associated with most of the varieties of petroleum will be noticed further on.

It is highly inflammable, requiring on the part of every one engaged in handling it the greatest caution, from the miner who extracts it from the earth, the shipper who transports it, the refiner who fits it for use, to the consumer who enjoys its benefits. Chemically speaking, it is a hydro-carbon of a complex character, whose composition and ultimate analysis have been a source of no little controversy.

It has been found in almost every part of the world: in small pools, exuding from the rocks, and from the soil, and in some places, as in the Island of Trinidad, in large lakes. In this locality on the shore of this immense deposit, where the liquid has cooled and become hard, the crust easily supports the weight of a man. As you advance to the centre, it softens, becomes fluid, the temperature rises, gaseous vapors are given off, while the centre presents a boiling mass of bituminous liquid, emitting stifling fumes. This form of petroleum when submitted to distillation and chemical treatment, will yield a small percentage of illuminating oil, but is chiefly used in the manufacture of concrete asphalt pavements, and in preserving timber from decay. Another variety of solid bitumen is known as "ozocerite," or mineral wax, which in its native state is of a yellow color, light specific gravity and inflammable. This peculiar substance is found in Austria, Moldavia, the Caucasus, and near the Caspian Sea, and has been used in all these countries for the purposes of fuel and illumination. The crude material, mixed with considerable earthy matter, is thrown into large iron tanks fitted with a steam coil. It is here melted and kept in a fluid state, in order to allow the impurities to subside. The clear oil is then removed to stills holding several tons, and there subjected to distillation. The oil collected from this process, greatly improved in appearance, is subjected to the usual chemical treatment. In order to obtain a perfectly white product, a second distillation is necessary.

When refined it is a beautiful, white, crystalline body, having the usual appearance and properties of paraffin wax. Its melting point is 140° F., 12° above that of ordinary paraffin, on which account it is greatly to be preferred, if employed in the manufacture of candles. In the process of this manufacture the liquid paraffin is allowed to pass from the condensing room into small iron vessels where it chills. The solidified mass in bags is subjected to powerful pressure; the oil is separated, forming a clear colorless oil of high illuminating power with a high fire-test. It may also be employed as a lubricant either singly or mixed with animal or vegetable oils.

Petroleum found near or upon the surface of the earth is always of a denser gravity than when it issues from wells of considerable depth; and it will be generally found that the lightest oils proceed from the deepest wells. It is not to be inferred from this, however, that the oils of a certain district proceeding from the same sand strata will be found to vary in density simply on account of the difference in the depth of the wells. In some localities it issues from the earth in such a state of purity that it is capable of being burned in lamps without undergoing the process of refining, but such instances are rare, and, generally, those varieties which have been so employed are greatly improved in their illuminating qualities by the modern process of treating these oils. The denser varieties wherever found are selected for lubricating purposes, while the lighter are distilled chiefly for illuminating purposes. With this

general and brief description of petroleum, we proceed to some particulars of its—

Geographical Distribution.

The fluctuations of the earth's surface have been so great, covering such vast periods of time and caused by such a variety of circumstances, that it is quite impossible to predict of any country from superficial indications and general topography that petroleum may or may not be found there. Nevertheless, it has been shown to be widely distributed and is found on every continent. As far as modern explorations have gone the largest deposits have been found in sections of territory lying at the base of, and parallel with, ranges of mountains; as, for example, the oil fields of America lying west of the Allegheny Mountains, the oil fields of the Pacific coast west of the great ranges of mountains fringing the Pacific Ocean, and the prolific fields of Southern Russia lying between the Caspian and Black Seas, and parallel with the Caucasian range of mountains. The causes of these disturbances, which have resulted in the upheaval of the great mountain chains and the bringing to the surface, or within the reach of man, the treasures of oil and coal and metal, belong rather to the domain of geology. In this connection, we will confine ourselves simply to the details of its geographical distribution and brief narrations as to where it has been discovered, the extent of the deposits, and its mode of extraction. These narrations will embrace accounts of oil found (1) in

North America, (2) South America, (3) Europe, (4) Asia, (5) other countries.

Canada.

Closely associated geographically, and, in all probability, as intimately related geologically with the great American oil territory, is the oil region of Canada. Indications of surface oil had for many years been observed in the township of Enniskillen in the extreme western section of the province of Ontario. These indications, however, so far from adding any value to the land in that vicinity seriously detracted from it. The dark oily liquid with its disagreeable odor was not then a marketable product. The streams of water were polluted with its nauseous taste, and where wells were dug the same manifestations were observed to such a degree as often to condemn them. In the year 1857 these surface marks attracted the attention of more skilful and better informed men. In this year the first well was dug, not drilled (for this art was quite unknown in this section at that time), resulting in a flowing well of considerable proportions. As no arrangement had been made to secure the output the most of the oil found its way into a neighboring stream and was lost, and no estimate, as far as we can learn, was ever furnished of its yield. Mr. J. T. Henry gives a very graphic description of the excitement produced by this first successful "oil strike." He says: "In an inconceivably short space of time enterprising operators from all parts of Canada and the adjoining Republic began to pour in. The needy denizens of

the Enneskillen swamps began to realize the fact that their slimy morasses might be confidently counted on to yield a revenue such as could never be hoped for from the richest and best cultivated agricultural soil in America. Land changed hands rapidly, and twenty-five hundred dollars an acre were paid for territory which previous to the great discovery could hardly have been given away. Stores and dwelling-houses sprang up all around with marvellous celerity, constituting the village of 'Oil Springs.' The supply of oil was inexhaustible. It was soon discovered, however, that in order to secure the oil in paying quantity these shallow wells could not be depended on. The regular drill was called into requisition. Shortly after, about thirty miles to the southeast of Oil Springs, near the village of Bothwell, another large vein of oil was struck where similar scenes of heated speculation were enacted; subsequently came into prominence, Petrolia, about five miles north of Oil Springs. The production of oil on Black Creek attained to enormous proportions in 1862." The first flowing well was struck there on January 11, 1862, and before October not less than thirty-five wells had commened to drain a store-house, which provident Nature had occupied untold thousands of years in filling for the uses of man. The yield was far greater than any possible demand at the time. The prices rapidly declined until it reached ten cents per barrel. It was allowed to flow without any attempt at times to collect it. It has been estimated that during this year that at least five millions of barrels of oil floated off on the waters of Black

Creek." As part of the history of the remarkable output of this region Professor Winchell furnishes "from personal examination and research" a list of some of the wells. The depth of the well is also given—

Depth of well in feet.	Name of well.	Daily yield in barrels.
104	Solis	600
108	Purdy	1000
115	Evoy Brothers	600
116	Jenery & Evoy	300
116	Fairbanks	500
130	Campbell	200
132	Bennett Brothers	500
136	Chandler	100
155	Jenery & Evoy	2000
157	Sifton, Gordon, & Bennett	150
158	J. W. Sifton	800
158	Shaw	3000
160	Wanless	200
160	McLane	3000
160	Ball	250
160	Rumsey	250
160	Whipple	400
163	Sanborn & Shannon	2000
163	Campbell & Forsyth	1000
163	Wilkes	2000
164	Bradly	3000
167	Webster & Shepley	6000
170	Liaunworth	500
170	Culver	200
173	Allen	2000
175	Barnes	300
178	Pettit	3000
180	George Gray	150
180	Holmes	500
187	McColl	1200
188	Swan	6000
212	Fiero	6000
237	Black & Mathewson	7500

The oil-producing territory here described contains about two hundred square miles. The petroleum is of a denser gravity than that obtained from the Bradford district of Western Pennsylvania, and ranks from 33° to 43° Baumé. It is also said to be more offensive in odor, containing a considerable percentage of sulphur, on which account it is both more difficult and more expensive to refine.

California.

Petroleum has been found in a number of places on the western slope of the mountains fringing the Pacific coast. In isolated and disconnected spots, from San Francisco down to Los Angeles and Santa Barbara, frequent surface indications are to be met with. A number of wells have been drilled, some of which have been productive and successful ventures. Several refineries have also been established, which have not only supplied the local demand for illuminating oil, but also that of several adjoining districts. During the year 1879, California produced 568,803 gallons of petroleum; year by year the production increased. In the year 1882 it mounted up to 4,903,920 gallons. I have no later returns. Recent statements, however, confirm the growing importance of this branch of industry. The 'San Francisco Chronicle' states "the results of its application as a fuel have so far been entirely satisfactory. On the steamer 'Thoroughfare,' the cost of the oil as a fuel was found to be 44 per cent. less for the first five months than for the corresponding period a year ago

(1884). It has also been employed on the great transfer steamer 'Solano.' The Central Pacific Railroad Company has recently introduced crude petroleum into nearly all of its steamers including the 'Oakland' ferryboat. The method of application is practically identical with the Russian, namely, by a steam jet. The nozzle is flattened so that the atomized oil is blown, in a sheet of flame, into the fire-box and under the boiler tubes. 100 gallons of the oil costing $4 will go as far as one ton of coal costing $7."

It is safe, however, to say that the large expectations which were formed at one time respecting the yield of California have not been realized, and that the more moderate statements contained in the report of the Geological Survey of California are correct.

"The expectations of extraordinary results that will admit of comparison with those that have been obtained in Pennsylvania must be set aside. The expectations of a fair return, and a permanently profitable investment, may be reasonably entertained; and on this basis the application of capital to this interest will make it of great importance to the State, and especially to that particular section in which the bituminous outcrops occur."

The West Virginia Oil Regions.

Following the line of the Alleghenies on the western slope, the oil region of Southwestern Pennsylvania appears to be continued into Northwestern Virginia. Indications of oil have been found in the Pan Handle and in the coun-

ties immediately south of the Pennsylvania line, and some experimental wells have been sunk with moderate success. But the great oil territory of West Virginia lies on the Little Kanawha and Hughes rivers, and on the numerous creeks and runs which pour into them, or into the Ohio, in Pleasant, Richie, Wirt, and Wood counties. The geological formation of this territory differs entirely from that lying beyond its limits. The upheaval, or oil belt, extends from the Ohio River opposite the Little Muskingum and Duck Creek about forty miles in a direction west of south, varying in width from three to ten, or perhaps fifteen miles. The rocks are peculiarly disturbed and broken. The hills along the numerous streams and gorges vary from one to three hundred feet high, and along the centre of the belt the rocks are nearly vertical, but dip at various angles as they recede on either side, forming what is called the east and west slopes. By some convulsion of nature the rocks appear to have been upheaved and separated, making deep ravines, gorges, and gullies, many of which have become the permanent beds of streams, along the bottoms of which is found "the boring territory," as indicated by the color and character of the rocks and the presence of oil both on the surface and oozing from the fissures of the rocks. Thousands of barrels of oil have been taken from pits sunk in the sand on the banks of the Hughes River. In 1860–61 the oil fever prevailing in the Venango Valley of Western Pennsylvania spread to this region, and several enterprising companies and individuals commenced boring for oil on the Hughes River at Oil Springs, and on the Kanawha

River at "Burning Springs." At the former place a small flowing well (from two to six barrels per diem) was struck, which continued to flow for a long time. At the Burning Springs the great Llewellyn well was struck which flowed for several months at the rate of from fourteen hundred to two thousand barrels per day. A great many wells were commenced at different localities on Cow Creek, Stilwell, Oil Creek, Walker's Creek, and the creeks near the Burning Springs, most of which produced oil in greater or less quantities. At this time Parkersburg was the great entrepôt and shipping port for West Virginia oil.

The oil found in West Virginia is of superior quality. Most of the shallow wells produce a very heavy lubricating oil, which commands a high price.

Southern Ohio Oil Region.

Directly across the Ohio River in a line with the West Virginia oil belt, is a productive oil territory embracing Washington, Meigs, Athens, Morgan, and Noble counties. On Duck Creek, which enters the Ohio River a mile above Marietta, a number of wells have been sunk to the depth of one or two hundred feet from which oil is obtained in sufficient quantity to warrant pumping. About ten miles from Marietta, near Lower Salem, evidences of active operations in oil become visible. Near Macksburg, the most valuable part of the Duck Creek region is reached. Here a number of wells were put down, varying in depth from eight hundred to eighteen hundred feet which yielded largely.[1]

[1] Petroleum, by J. H. A. Bone, Phila., 1865.

Oil Wells of Terre Haute, Indiana.

"A well lately sunk at Terre Haute, Indiana, in search of fresh water, has shown the existence of a productive source of oil in that region. It was carried nineteen hundred feet, and yields about two barrels of oil daily. A second well, a quarter of a mile east of north from the first, now gives a supply of twenty-five barrels of oil daily. After passing through one hundred and fifty feet of superficial sand and gravel, the boring was carried to the depth of sixteen hundred and twenty-five feet, when oil was struck. According to Professor Cox, the strata passed through are as follows: Coal measures seven hundred feet; carboniferous limestone, with underlying sandstones and shales, seven hundred feet; black pyroschists, regarded as the equivalent of the Genessee slates, fifty feet. Beneath, at the depth of twenty-five feet, in the underlying Corniferous Limestone, the oil vein was met with. The oil in the first well was found at the same horizon.[1]

Kentucky.

In Cumberland County, or Renox Creek, mineral oil or petroleum rose to the surface with the saline water, after boring one hundred and fifty to one hundred and sixty feet, and accumulated in sufficient quantity to make it a profitable article of trade. Thousands of dollars worth of this oil are said to have been taken from this spring in former times and sold at the rate of sixty dollars per gross, pint bottles.

[1] Dr. T. Sterry Hunt, Geological Report, 1870.

Illinois.

Oil has been found in small quantities in two or three counties in the southeastern portion of this State, and it is by no means improbable that paying wells may hereafter be obtained in that portion of the State. The counties of Gallatin and Saline, and those north of them, and lying in the valley of the Wabash River, will, in my opinion, be most likely to afford productive oil wells.[1]

Besides the States which have already been mentioned, petroleum has been found in variable quantities in Michigan, Illinois, Missouri, Kansas, Alabama, Louisiana, Nebraska, Montana, Wyoming, Dakota, Colorado, and New Mexico. Wells have been drilled in several of these States by oil prospectors, but, as far as I am able to learn, they have not been paying adventures.

The oil fields of Pennsylvania and Western New York will be described elsewhere.

Mexico.

It is stated that a company composed of Boston (Mass.) capitalists has secured large interests in the Tuxpan oil region in the State of Vera Cruz. The company has been prepared for extensive developments for more than a year. The geological formation of this section resembles that of the Pennsylvania oil region, and there are many oil springs. The oil field lies at the base of the San Felipe Mountains, southwest of the port of Tuxpan. The petro-

[1] Geological Survey of Illinois, A. H. Worthen, Director, 1866.

leum, which resembles in gravity and appearance the Pennsylvania oil, oozes from the rocks in many places. Around a small lake in the district, Lake Culco, there are forty oil springs. The oil runs from them in such quantities that the lake is constantly covered with it. Pennsylvania oil-well drillers are superintending the development of the district.

There are also extensive petroleum deposits in the State of Tabasco. The oil fields are forty miles from the capital in the San José Mountains.

West India Islands.

Petroleum has been found in greater or less quantities in nearly all of the West India Islands. In Cuba it has been known to exist for many years. A variety of liquid asphalt, known as "Barbadoes tar," has been exported from this island. It is about the consistency of gas-tar, and has been used as a coating for the preservation of timber. In some parts of the island it is quite abundant, and some years ago attracted the attention of some engaged in the search for oil, and arrangements were made to drill. We have never learned, however, that oil in paying quantities was obtained. The want of success in this and other fields is in some measure to be attributed to the very low price of the Pennsylvania product.

Peru.

The existence of petroleum, if tradition received through the Spanish conquerors of this country be correct, has been

known for several centuries. The same crude method of collecting adopted by the primitive races of other countries was practised here; shallow pools were dug, and the oil which collected in them was dipped out into earthen vessels. It was sometimes used as a fuel, or allowed to evaporate to the consistency of pitch. Afterwards it was heated by artificial means and used for coating the insides of earthenware vessels. It is said that the Spanish government long held a monopoly of the trade of manufacturing and selling this coating material, which was chiefly employed on liquor jars. From the best information we can gather, the attention of American capitalists was first called to this oil field in the year 1863, through the instrumentality of a gentleman (Mr. A. E. Prentice) employed by the Peruvian government in the capacity of an engineer. He communicated the facts to a relative actively engaged in petroleum enterprises in Western Pennsylvania.

The oil lands of Peru are in the coast region bordering on the Pacific Ocean. They extend from Cape Blanco to the Tumbez River, a distance of about 120 miles. The tract is 60 miles wide and contains 4,408,000 acres. In places along the coast, where the waves of the Pacific have worn away the rocks, the oil trickles out at low tide, and for 90 miles this outcrop may be followed. The village of Zorritos is the present centre of operations, which are almost entirely confined to the Mancora estate, one of the largest in the country. The existence of deposits of petroleum had been noticed by the agent of

the estate, Mr. Alexander Rudden, who proceeded in a small way to develop the oil by digging pits to the depth of twenty or thirty feet, which were found to yield considerable oil. He communicated the result of his operations to Mr. Prentice, who responded to his invitations to join with him in the search for oil. In the fall of 1863 a well was sunk in one of the pits above mentioned. At the depth of 140 feet from the surface, and 60 feet below the ocean level, a vein of oil was struck, but the yield was small. Mr. Rudden became discouraged, and suspended further operations in this line. At this juncture, Mr. Prentice communicated with a relative of the same name, in Western Pennsylvania, as stated above, and earnestly invited his attention to this new field. In the year 1867 operations were begun in earnest. A well was put down near Zorritos; at the depth of 146 feet a volcanic formation was reached by the drill, and oil was found; this well yielded by means of the pump 60 barrels per day; we are not informed how long it continued to produce that quantity. A second well was drilled to the depth of 230 feet, piercing a second vein of oil; the results of this operation were disappointing, being only 10 or 12 barrels per day. Being satisfied, however, of the existence of oil on this tract, and that with proper management it would yield a profitable return to the investment of capital, he proceeded first to negotiate with the proprietors of the property to secure the entire control of the oil interest thereof. This having been accomplished, a stock company with ample capital was organized, and in the year

1876 another well was drilled to the depth of nearly 500 feet; at this depth the tools dropped into a fissure—in the true oil-bearing sand—and oil commenced to flow through a 6-inch casing at the estimated rate of 1000 barrels a day. Another well was shortly after put down in the same vicinity, and yielded 600 barrels per day. It is stated that there are some points of resemblance in topography and its geological formations between this oil territory and that of Western Pennsylvania.

"It is a singular coincidence that this oil belt corresponds with the oil region of Pennsylvania, as both are intersected by the 80th degree of longitude. It is also worthy of note that the mountain range of the Andes to the east contains large deposits of anthracite coal, and that this coal deposit is about the same distance from the oil field of Peru as our Allegheny anthracite deposit is from the Pennsylvania oil region. A coating of sand about eight inches thick covers the surface of the Peruvian oil field. A fossiliferous deposit of marine remains is found on the surrounding hills from 250 to 300 feet above the level of the sea. The same deposits are also found on the bottom of the lands, which proves that this part of the continent has at some period of time been covered by the sea. From all wells struck on this territory great volumes of gas continually issue. The gravity of the oil is from 40° to 50° Baumé. In color it is a little darker than Pennsylvania oil, and has the same odor. It yields, when refined, from 70 to 75 per cent. of 110° fire-test oil, and is a superior article. The company refines its own

oil, and finds a ready market for its product on the Pacific coast, Australia, and New Zealand. The company is known as the Peruvian Oil Company; capital, \$5,000,000."[1]

Ecuador.

This province of South America lying immediately north of Peru, resembles it so closely, topographically and geologically, that we are quite prepared to learn from the recent geological report to the government of Ecuador of the existence of petroleum in this country. Raymond de Peiger, engineer and geologist to the government, in his report to the President of the Republic, says: "Petroleum is to be found in this country in very large quantities. On a surface of about four square leagues from the sulphurous spring of San Vicente to the seashore, wells have been sunk and the bituminous matter obtained in a liquid state. Its consistence is not the same in the different wells. In some of these it is fluid like whale oil, in others it has the consistence of butter at ordinary temperature. At the surface or upper part of many wells it can be seen in compact hard masses, which probably have been formed by the evaporation of the liquid. This oil has a dark-brownish color, which gets darker with the greater consistence of the oil. In one place where it oozes from the bed of a dried-up stream, the bituminous matter has a greenish color. Its smell is not disagreeable, which is gene-

[1] Henry. Early and Later History of Petroleum, Phila., 1873.

rally the case with many of the American and especially the Canadian oils. As the inhabitants have neither the knowledge nor the implements required, the works are very crude. Pits from ten to twelve feet deep are dug into the sand till clay is reached, and when the oil, which oozes from all sides, has filled them, it is dipped out. Near the wells are primitive furnaces built with sun-dried clay, on which are open iron boilers. The bituminous matter is thrown into these vessels and cooked until all the volatile products disappear, leaving a thick pitch. It is not supposed that the petroleum has been formed in the upper sandy deposits. Its presence there can only be explained by the escape of the bituminous matter from the fissures in which it was contained. We may then safely admit that although large quantities of oil are to be found in the sand, it is only the mere waste of the real springs. Deeper sinking without any doubt would be very profitable and yield immense proportions of petroleum." The proximity of this oil territory to the sea certainly gives to it important commercial advantages. At a very small expense oil may be brought to the port of Santa Elena by means of pipes. It has been said that the oil territory above described has been leased for a long term of years to a company of American capitalists, who are preparing to develop the same.

Alsace.

The first authentic record of the discovery of petroleum in this part of the world informs us that it was first seen

in this ancient province of Germany on the border of the Rhine in the year 1735 by Dr. Antoine Le Bell, a naturalist and close observer. It was observed at or near the surface. Its greasy unctuous qualities first attracted his notice; a close examination of its character and qualities revealed the fact that it was one of the many forms of rock oil. He experimented with it as a lubricator, and being satisfied with its results, proceeded at once to develop the hidden wealth of his estate. He sank a shaft, and at the depth of fifty feet uncovered the sand rock rich in oil. It appears from the facts that we are able to gather, that the texture of this rock is wholly different from the sand rocks or oil-bearing strata of Western Pennsylvania. It is more compact, more finely grained and tenacious in structure. The oil does not flow freely from it. The sandstone was therefore quarried very much as coal is mined—drawn up in buckets to the surface. The first product of this mining operation was subjected to a very crude process in order to extract the oil from it. It was placed in large iron cauldrons covered with water, and heat applied; as the oil was thus "boiled out," it rose to the surface of the water and was skimmed off. At the present time two processes are employed, viz: the one just described, and distillation from iron retorts similar to those used in other parts of Europe for the distillation of bituminous shale. Excavations have been made three hundred feet deep and the miners descend to their work lighted by Davy safety lamps, which they strap to their breasts. The property is still in the possession of the Le Bell family. The character of

the oil is that of an excellent lubricator. The yield from the sand rock is about sixty per cent., worth from five to eight dollars per barrel. It is said that the "surface indications" are good also in adjacent parts of the country.

Hungary and Galicia.

Along the base of the Carpathian Mountains oil has been found in considerable quantities. We have already alluded to the existence of ozocerite, or "mineral wax," found in this part of the world. "On the Galician side the oil belt, though extending for two hundred miles, is explored at three principal centres: New Saudac on the west, Dukla, Krosno and Sanock in the middle, and Borslau in the east where the "mineral wax" is found. From time immemorial the peasants of Boberka on the banks of the Jasielka between Dukla and Krosno have noticed oil oozing from joints of the sandstone rocks and standing, especially in dry seasons, on the little pools of water. They collect it to grease their wagons and fire it off on festival occasions. In 1860, M. Luckaselwitch, hearing of the American petroleum wells, experimented with it in his laboratory, and then commenced work on M. Klobassa's lands, but with very poor success. In 1861, he transferred his search to a place farther east, and struck oil at a depth of 50 feet, which gave a very promising yield. His second well yielded 600 barrels. Wells multiplied until in 1870, the yield amounted to $70,000 per annum, giving a profit of $50,000. Seventy-seven wells are ranged along the axis of a sharp anticlinal, one-third of a mile long, none being

more than 80 feet off the straight line, and the oil from all flows through a common pipe to one reservoir. Some of the wells are 350 feet deep, but no law of depth has been obtained. Shafts seven feet square are sunk about 70 or 80 feet to the sandstone, and bore-holes are continued from this downward. Gunpowder is used in shafting, and strong ventilating fans blow out the gases. Lights are forbidden, and accidents are few. The boring is very rude, being done by four hands without machinery.

On reaching the oil stratum a great quantity of carbonic acid gas mixed with hydrocarbons, escapes from the well followed by the oil, which rises to the surface of the water, filling the shaft. A small hand pump is used to draw off the water and oil into barrels, from which the water is allowed to escape by gravity.

India.[1]—*Makum.*

In 1865, the petroleum springs in the Makum coal field were visited by Mr. H. B. Medlecott, who stated that, though their discharge was small, they were the most promising he had seen. The gas was so abundant and so continuously poured forth, that when lighted it flamed without intermission. This, coupled with the fact that there was no water discharge, led Mr. Medlecott to recommend boring in order fairly to test the supply. This was done by Mr. Goodenough, a member of the firm of Messrs. Mackillop, Stewart, & Co., of Calcutta. Oil was struck at

[1] Geology of India, Geological Survey, 1881; Calcutta, V. Ball, Director.

118 feet, and it immediately rose 74 feet, or to within 44 feet of the surface; about 300 gallons were drawn, after which the yield became irregular; altogether eight holes were drilled. Well No. 5 appeared to give the best results, a regular record of the yield of this well was kept from January 8, 1868, when it began to flow, until August 22, after which no record was kept. The lowest record made was at the rate of 300 gallons per day, the highest record was at the rate of 3600 gallons in the same time. The specific gravity of this oil was 0.971. A portion was submitted to distillation, it began to boil at 460° F., and yielded only 20 parts out of 1000 below the temperature of 500° F. We have no estimate of the value of this oil for lubricating purposes, but it is evidently of too low gravity to yield much illuminating oil.

Upper Burmah.

At Yenan-Gyoung (lat. 20° 18′, long. 95°), there are a large number of oil wells; they are four feet six inches square, and descend vertically from the top of the plateau to depths of from 250 to 330 feet. Over each well there is a rude cross bar and drum by which an earthen vessel is lowered and drawn up again by a man who walks down an inclined plane with the rope to which it is attached. This is then poured into a larger vessel. It is said there are in this vicinity about 200 wells, some of which yield about 250 gallons per day. The average yield of these wells would be rather less than one-half this amount. An oil duct or pipe line was in the course of construction. It is made of

bamboos with the inside lacquered, which are supported on stays and run from the wells to the river bank, a great loss of oil by evaporation being inevitable, but the system is a great improvement on the old one of carrying the oil in earthen vessels on a cart. The yield, according to the Government register, of the wells of this district for 1873 was about 96,000 barrels.

The specific gravity of this oil is 0.862 according to analysis made by Messrs. C. M. Warren and F. H. Stover in 1865. This oil yielded the following hydrocarbons:—

Benzol, $C_{12}H_6$.
Toluol, $C_{14}.H_8$.
Xylol, $C_{16}.H_{10}$.
Cumol, $C_{18}H_{12}$.
Butylene, $C_{20}.H_{20}$.
Margarylene, $C_{22}.H_{22}$.
Laurylene, $C_{24}H_{24}$.
Cœmylene, $C_{26}.H_{24}$.
Naphthaline, $C_{20}H_8$.

The analysis of this variety of petroleum as above given, is copied from the government geological report of India. It is the only oil from this region that has been carefully studied.

The report gives accurate descriptions of about thirty oil fields.

Oil Wells in Burmah.

The following account of the ancient petroleum wells of Burmah is an abridged statement of various records which are authentic and trustworthy. Dr. James M. Robertson,

at a meeting of the Geological Society of London, held in the year 1879, gave a very graphic description of a visit recently made to the wells. In the vicinity he noticed what he terms mud volcanoes, where the confined marsh-gas, a constant associate of petroleum, would at times throw up with some violence large quantities of mud and water with the simultaneous escape of volumes of inflammable gas. The petroleum of Cheduba, Ramree, and the Barongat Islands is of a light specific gravity, of a brown color, and contains a large proportion of burning oil. The oil was collected generally from shallow pools. In some places wells were noticed to be twenty to thirty feet deep; in these localities the oil-bearing strata were further removed from the surface. As a rule, however, the wells or pits were quite shallow, and the oleaginous spots appeared to have no connection with each other. In 1877 this locality was inspected by an English company, which prospected this section, hoping to improve upon the crude methods of the natives for the extraction of the oil, and thus obtain a much larger yield. From a well thus operated a yield of only about 500 gallons a day was obtained. The venture does not appear to have been a paying one, as we have no further account of it. Dr. Robertson then proceeded to Upper Burmah to inspect the "*King's Well*" which has for centuries yielded large quantities of oil. On the voyage up the river Irawaddy, the odor of petroleum pervaded the atmosphere. On his arrival in the vicinity of the wells he beheld a fleet of vessels loaded with oil in bulk, and the shore covered for acres with great earthen jars filled with

oil. The wells were situated a few miles inland. In this district there were 800 wells occupying the top of a broad ridge between two parallel ravines. The space over which they were scattered did not appear to exceed 500 acres in extent. According to the statement of the natives, no oil had ever been found beyond the limits of the ravines. He was also informed that since the discovery of the large wells in America, and the introduction of the highly refined oil from this country, the demand for the product from these wells had considerably diminished. The oil-bearing stratum in this district lies at a much greater depth than in Cheduba. It is about five feet in thickness, and highly charged with petroleum. In some places the excavations were made to the depth of 400 feet, in others the oil was reached at depths varying, according to the surface level, from 120 feet to 300 feet. As might be expected, from the crude method of sinking these wells and for the subsequent extraction of the oil, the operation is attended with considerable risk to the health of the men engaged in the work, owing to the well known intoxicating effects of the lighter vapors of the oil. There is also danger from fire. The wells were placed about forty feet apart, and the oil was drawn up in buckets as from an ordinary well as fast as it accumulated at the bottom. Some wells were much more productive than others, varying in this respect from 2 gallons per day to 400 gallons; some wells had been known to yield from 500 to 700 gallons per day for the space of three years, and one well was pointed out that had yielded 700 gallons per

day for a much longer period. The oil from these wells is described as being of a dark green color, and viscid in consistency, and becoming almost solid at a temperature of 60° F. The sp. gr. was 0.810. The odor was rather pleasant than otherwise. The newly drawn oil had a temperature of 88°, or 26° below the temperature of the atmosphere in the shade at the time the test was made. It was found to yield about 70 per cent. of burning oil with a flashing point 20° higher than American oil, and to be in every other respect a superior product. At the time of this examination the daily yield of this district was about 6000 gallons, or about one-half what the wells could produce under proper management.

Japan.

This account is extracted from 'The Geological Survey of the Oil Lands of Japan,' made by Benjamin Smith Lyman, 1877, and published in Tokei.

"After about two days more with the transit practice of the fifth party, I went on the evening of the 22d of August to Kusôdzu, a couple of leagues from Wakinomachi towards Idzumozaki, and on a high mountain. Close by are several oil wells and natural exposures, and it is said that the oldest wells of Echigo were here, and they are supposed by the inhabitants to have been dug several hundred years ago. It is said in the Japanese history, called Kokushiriyaku, that rock oil, or 'burning water,' was found in Echigo in the reign of Tenjiteno, which was 1260 years ago, or about A. D. 615, and that

was probably at Kusôdzu, where there are still very old natural exposures, as well as dug wells. The name of the place, Kusôdzu, is the name given in the country to rock oil, and means 'stinking water,' and the very fact that the word is by contraction so much changed from its original form, 'kusaimidzu,' shows of itself considerable antiquity. Here and there I could be carried close to the wells that they were drawing the oil from in buckets—in some cases a monthly operation; and, on one excursion, I saw at Aburadaira, a few furlongs south of Kusôdzu, a new well that they were digging, at that time about 300 feet deep, and could from actual observation compare the methods in use with those adopted in working oil wells in America and other western countries, and judge what would be the best plan under the circumstances for our trial wells and for general use in the Japan oil regions. . . . . The present mode of working is very simple, and not many more men are needed than for boring with steam. The digging is all done by two men, one of whom digs in the morning, from nine o'clock until noon, and the other from noon until three. The one who is not digging works the large blowing machine or bellows, that continually sends fresh air to the bottom of the well. The blowing apparatus is nothing but a wooden box, about six feet long by three wide and two deep, with a board of same length and width, turning in it upon a horizontal axis at the middle of each long side of the box, and with a vertical division below the board between the two ends of the box. The workman stands upon the board and walks from one end

of it to the other alternately, pressing down first one end and then the other. At his first step on each end he gives a small blow with his foot, so as to close with the jerk a small valve (0.3 foot square); beneath each end of the board is a valve that opens by its own weight when the end of the board rises. The air, therefore, is driven first from one end of the box, then from the other into an air-pipe about 0.8 foot square, provided at the top, of course, with a small valve for each end of the blowing box, and made of boards in lengths of about six feet, and placed in one corner of the well. The well is besides timbered with larger pieces at the corners and light cross-pieces, which serve also as a ladder for going up and down, though at such a time, in addition, a rope is tied round the body under the arms and held by several men above the mouth of the well. The earth or rock which is dug up is brought out of the well in rope-nets by means of a rope that passes over a wheel one foot in diameter, hung just under the roof of the hut about ten feet above the mouth of the well, and is pulled up by three men, one at each corner of one side of the well, and the third in a hole two or three feet deep and a foot and a half wide, dug alongside of the well."

Notwithstanding the great labor expended in digging these wells, the yield appears to be small; the best only 19 barrels a day. There were in this section 178 productive wells. The oil is dark green, marking about 43° Baumé. The report is very complete, furnishing accounts of a large number of districts visited, and giving in detail the number of wells in each and their yield.

CHAPTER IV.

RUSSIAN PETROLEUM.

The recently published accounts of the productiveness of the oil region bordering on the Caspian Sea in the vicinity of Baku are the most extraordinary ever put forth respecting any country. For several years past items respecting the large yield of oil from that section would occasionally appear in the daily press, and, from time to time, warnings would be heard that, sooner or later, the supremacy of American oil in the European markets would be lost, and that this region, in the near future, would become a formidable rival for the supply of petroleum. American producers and refiners have hitherto affected to ignore the claims and statements which have reached us, but we think a careful perusal of the facts of the case we propose to present, must arouse both the producer and shipper of this article to prepare for the most powerful competition they have yet encountered. So late as January 14, 1885, the following telegram was received, which clearly shows the activity prevailing there. This cable dispatch announces, "The Black Sea Steam Navigation Company has given orders for the building of a fleet of steamers in Sweden and England. Each steamer is to be fitted with petroleum tanks and to have a capacity for 1500 tons per

trip. *The design is to compete with the American petroleum trade.* M. Trodel, a Russian contractor, is preparing to send oil in bulk to London from Libau, on the Baltic, next spring." Fifteen hundred tons represent nearly fourteen thousand barrels. This dispatch does not state the number of steamers to be built, which of course will depend upon the success of the enterprise; but it is safe to say no competition of this magnitude has ever before been met with in any foreign market. The reader will also shortly be informed that the port of Libau on the Baltic is only one of the many depots already established by the immense concern, The Nobel Brothers, and forms part of their plan for the complete occupancy of the European markets.

We derive our information respecting the wonderful development of this modern Russian industry chiefly from the accounts recently published by Mr. Charles Marvin,[1] a writer who appears to be thoroughly well informed on the subject about which he writes. The oil territory to which attention is now being directed is situated in the southeastern part of Russia, lying between the Caspian Sea on the east, and the Black Sea on the west, in the region known as the Caucasus. This by no means limits the oil region, which, from surface indications is known to extend as far north as Saratov on the Volga River, and to Afghanistan toward the south and east. The chief point of interest now is Baku, a port on the western coast of the Caspian Sea. Petroleum has been known to have

[1] Region of Eternal Fire; Petroleum Region of the Caspian. London, W. H. Allen & Co., 1884.

existed in this region for a period of 2500 years. Six hundred years before the Christian era, Baku was a resort for the fire worshippers from the east. At this time it was under the Persian rule, and the flames of fire issuing from the ground on the banks of the sea suggested this to the superstitious mind of that age, as a spot particularly suitable upon which to render homage to the "fire god." Six centuries after the birth of Christ we read that the Byzantine emperor, Heraclius, on his triumphant march to the conquest of Persia, sought out and destroyed the temples of the magi there. These were afterwards rebuilt, and it is a matter of tradition that this superstition has been maintained in the vicinity until within a few years. There appears to be a clear chain of evidence existing from the remote antiquity which we have mentioned, both of the presence and of the abundance of oil in this region. From the journal of Marco Polo, the celebrated traveller, written in the thirteenth century, we learn that at Baku was "a fountain of oil of great abundance, inasmuch as a hundred shiploads might be taken from it at one time. This oil is not good to use with food, but 'tis good to burn, and is also used to anoint camels that have the mange. People come from vast distances to fetch it, for in all countries round there is no other oil." From this statement we at least learn that the trade in Russian petroleum is not a new thing.

The value of this territory on account of its wealth of oil was the occasion of many sanguinary contests between the Armenian emperors and Persian shahs, until finally Russia, in the time of Peter the Great, absorbed the Cau-

casus, and one of his first acts was to have shiploads of petroleum dispatched up the Volga for the use of the towns lying on its banks." We learn from the statement of Jonas Hanway, 1754, that "the Persians load it in bulk in their wretched vessels, so that sometimes the sea is covered with it for leagues together. When the weather is thick and hazy the springs boil up the higher, and the naphtha often takes fire on the surface of the earth, and runs in a flame into the sea in great quantities to a distance almost incredible. In clear weather the springs do not boil up above two feet or three feet; in boiling over, the oily substance makes so strong a consistency, as by degrees almost to close the mouth of the spring; sometimes it is quite closed and forms hillocks that look as black as pitch, but the spring which is resisted in one place breaks out in another. Some of the springs which have not been long open form a mouth eight feet or ten feet in diameter. The people carry the naphtha by troughs into pits or reservoirs, drawing it off from one to another, leaving in the first reservoir the water or the heavier part with which it is mixed when it issues from the spring. It is unpleasant to the smell, and is used mostly amongst the poorer sort of the Persians and other neighboring people, as we use oil in lamps, or to boil their victuals; they find it burns best with a mixture of ashes. As they obtain it in great abundance, every family is well supplied."

The same writer notices two varieties of the oil, the heavy and the light; of the latter he says, "the Russians *drink* it both as a cordial and medicine, but it does not

intoxicate." In bringing the history of this remarkable place down to our times, we reluctantly pass over a number of interesting statements of travellers and others. In 1801, Baku, which on account of its valuable mineral wealth and the supposed sacredness of its fire-producing soil, had been the scene of many hotly contested battles, again passed under Russian supremacy. From the 'Geographical Memoir of the Persian Empire,' published in 1813, we learn that "the quantity of naphtha produced in the plain to the southeast of the city is enormous. The oil is drawn from wells, some of which had been found by a computation of the inhabitants to yield from 1000 to 1500 poods a day. These wells are to a certain degree inexhaustible, as they are no sooner emptied than they begin to fill, and the naphtha continues gradually to increase, until it has attained its former level. It is used by the natives as a substitute for lamp oil, and when ignited emits a clear light with much smoke and a disagreeable smell. The whole country around Baku has at times the appearance of being enveloped in flames. It often seems as if the fire rolled down from the mountains in large masses with incredible velocity; and during the clear moonshine nights of November and December a bright-blue light is observed at times to cover the whole western range." In 1819, according to Colonel Yule, "the quantity of petroleum collected from the springs about Baku was estimated at 241,000 poods, nearly 4000 tons (or about 35,000 barrels), the greater part of which went to Persia." We may form some idea from this statement how copious were the surface

supplies. Up to this time, and for many years after, the method employed by the natives for gathering the oil was both crude and wasteful. Shallow pits were dug, and as the oil would percolate through the superficial earthy strata and collect in them, it would be bailed out.

We now come to a period in the history of Baku, when, it may be said, it began to feel the impetus which the developments in the far-distant oil region of Western Pennsylvania had given to the petroleum industry in many other parts of the world. In 1860, we learn of a "naphtha manufactory" having been established in the vicinity of Baku, which paid to the Crown of Russia an annual rental of 117,000 roubles (about $87,000) from which fact alone we may form an idea how extensive the trade was even at that early date. Mr. Osmaston describes many scenes peculiar to the place, and which have been so frequently described by others. Among other phenomena he noted the petroleum fires on the surface of the Caspian Sea. In many places, quite frequently, the water is covered for many square miles with petroleum, which boils up from the bottom of the sea, thus clearly showing that the oil-bearing stratum extends from Baku on the western coast of the Caspian Sea, that it underlies this body of water and reappears in the trans-Caspian region, where the same abundant surface indications present themselves that we find on the opposite shore.

In 1870, we hear for the first time of its favorable comparison with American oil. Mr. Herbert Barry, an

engineer in Russia, says in his work on 'Russian Metallurgical Works:' "Petroleum exists in great quantities on the borders of the Caspian Sea near Baku. Its quality is considered equal or even superior to the American oil." In 1872, we learn of two oil refineries being established, and have the first notice of the employment in this region of the oil as "liquid fuel" in the production of steam. In this respect the American engineer was as many years ahead of the Russian at that time, as the Russians are ahead of us at the present time in the same field.[1]

The following interesting account of the state of affairs at Baku at the time mentioned is given by Major Marsh:—

"The afternoon was devoted to the great natural wonders of Baku, petroleum, and the everlasting fires. At Surakhani the whole country is saturated with petroleum; on making a hole in the ground the gas escapes, on lighting which it burns for a very long while, one of the few spots on earth where this extraordinary phenomenon can be seen. When there is no wind the flame is dull and small, but in a gale it roars and leaps up eight or ten feet. There are two naphtha refining establishments at Surakhani, the furnaces of which are entirely heated by the natural gas, which is collected, as it rises out of the ground,

[1] In this connection we have no intention to underestimate American ingenuity. The explanation of this change of affairs will be found in the relative cost of the different kinds of fuel employed. In this part of Russia coal is scarce and dear, while petroleum can be had in unlimited quantity at an exceedingly low price, while in the petroleum regions of Pennsylvania coal is abundant and cheap, petroleum commands a relatively higher price.

in iron tanks and led on by pipes. At night the whole place is lighted in the same manner, by ordinary gas burners attached to the walls. On returning home in the evening we saw the silent waste, lit up by various fires, each surrounded by a group of wild Tartars cooking their food by its heat. The naphtha springs or wells are about five miles off, and the oil is brought in casks, in the crude state, as it is pumped out of the wells, a thick black fluid. The engine that works the government patent 'slip' uses this naphtha instead of coal for fuel. The oil is brought out of a tank by pipes, and is blown into the grate by the force of steam, the heat and flame being regulated with the same ease as a gas lamp, and steam can be got up in the large furnaces in a quarter of an hour. *It is cheap, and has the advantage of being clean and easy to manage.*"

This last clause, which we have purposely italicized in order to draw the attention of the reader to its importance, expresses precisely the present sentiment prevailing in that section, with reference to the employment of petroleum as a fuel, where its use has increased more than a thousandfold.

In the year 1873, General Valentine Baker passed through Baku, and alludes to the "apparently inexhaustible supply of naphtha" found in that vicinity, and also refers to the gas bubbling up to the surface of the Caspian Sea in immense quantities. His comments on the influence of its introduction as a liquid fuel are interesting in this connection. "It promises to have a great effect in facilitating steam communication on the Caspian. The discovery of the immense supplies of naphtha at Baku, and

its simple application to steam purposes, has obviated the disadvantages which previously existed through the high price of coal. The pure naphtha as drawn from the wells is not used; it is the refuse after distillation, which is found so valuable for steam purposes. This is not highly inflammable and its use seems perfectly safe and thoroughly under control. Vessels originally fitted for burning coal can burn this naphtha with very little alteration. The naphtha is forced into the furnace in the form of spray mixed with a jet of steam. One stoker is sufficient for a large steamer. All the engineers of the vessels using it speak in the highest terms of this fuel."[1]

Until the year 1873 petroleum mining was a close monopoly, paying, we presume, a handsome royalty to the Russian government. At this time, it appears, its eyes were opened to recognize the still greater benefits that were likely to result from abolishing the restrictions hitherto placed upon its production. In the year 1875 we have for the first time some reliable statistics respecting the actual production of the wells and the prices of the oil. Mr. Arthur Arnold, M.P., in this year furnishes the following interesting item of information: "The engines of the *Constantine*, the ship on which the Shah traversed the Caspian, were driven with petroleum. Coal, the captain told us, costs eighteen and a half roubles per hour, while petroleum costs only one and a half roubles, a reduction from fifty shillings to four shillings. In a few years Baku

[1] "Clouds in the East," London, 1875.

will be united by railway with Tiflis and the Black Sea, and then probably all the steamships on the Euxine will be supplied with the same inexpensive fuel. For two or three miles along the shore of the bay the many buildings in which the oil is refined by itself as fuel pour forth dense smoke, and eight miles from the town are the springs. The average depth at which the oil is touched seems to be about one hundred and fifty feet; the wells are for the most part nine inches to a foot in diameter. From the first well we visited a small steam engine with most primitive gear was lifting about 400,000 pounds of petroleum per day. The oil is of a greenish color, and as it is drawn up is emptied into a square pit dug in the surface from which men take it in buckets and pour it into skins or barrels, the charge at the wells being at the rate of 1½*d.* per 50 lb. weight of oil."

In the year 1881 we have to note the wonderful progress made both in the production of the oil and in the trade resulting therefrom. Mr. Edward Stack, of the Indian Civil Service, writes from Baku in August, 1881: "The output of the naphtha springs at Baku was about 160,000 tons last year, and is increasing yearly. Difficulties of transport hinder this trade to a certain extent, but these will be largely surmounted if the American plan be adopted. At present the naphtha is transported chiefly by water. A hundred and fifty vessels lie in the harbor, mostly schooners of 90 to 200 tons, but some three-masted steamers belong to the port, the largest being of 1000 tons burden. Nobody can spend half an hour in Baku

without seeing that it is a very rich and flourishing place."

We shall have occasion further on to furnish more particular information respecting the enormous yield of the wells around Baku, and therefore in this connection only incidentally allude to the statement of the geographer, who notices the "700 oil wells" which have already been drilled, none of which show any signs of exhaustion; but says that "immense loss is caused by the ignorance of those engaged in the trade. Thus, a well at Balakhani, yielding 4800 tons of naphtha daily, ran waste for four weeks before a reservoir could be prepared to receive the oil." These figures are so startling that we have more than once looked before we have dared to place them a second time on record—4800 tons! This means, when reduced to the American mode of computation, allowing seven pounds of petroleum in round numbers to the gallon, and forty-two gallons to the barrel, 36,571 barrels per diem! This so far exceeds anything we have ever known in America, that we are sure this statement will be received with a smile of incredulity. The largest record we have of any well in this country[1] is that of a well in Thorn Creek, Butler County, Pa., drilled 1884, which is said to have flowed for a few hours at the rate of nine or ten thousand barrels per day. Every account of the oil district of Baku which we have examined bears

[1] To which allusion is made in a supplementary article on 'Petroleum' in the 'Encyclopædia Britannica' (ninth edition, American reprint, 1885).

testimony to its astonishing productiveness. This testimony we believe to be reliable, and we must accept the verdict pronounced by Professor Mendelaieff, the celebrated Russian scientist, who, after a visit to Baku in 1882, said: "Comparing results achieved in the two countries on one side and the average depth and total number of wells on the other, it may justly be stated that the natural petroleum wells of Baku, as far as our knowledge goes, have no parallel in the world."

The petroleum district of Southern Russia is not only more productive than any other of which we have any account, but it is also more extensive. If the reader will consult the map of this region with a few points to guide him, he may form a tolerably correct opinion of the vast extent of territory which seems to be filled with oil. Commencing with a point on the Taman Peninsula, jutting into the Black Sea on its northern boundary, a direct line may be drawn running southeast to Baku on the Caspian Sea, a distance of about 1500 miles. This line traverses the oil belt. The width of this belt has not yet been accurately determined. Ten miles may be safely put as the minimum estimate, which would give, as the least calculation, an area of 15,000 square miles. Oil has been found in paying quantities in a number of places all along the course of this belt. The prolific yield of the wells at Baku and the advantages offered at that place for shipment seem to preclude any vigorous search for oil in any other locality. It was, however, in the northwestern extremity of the oil belt that the first spouting well or oil fountain

made its appearance in the Caucasus, where it formed, in 1866, on Novoseltseff's estate, an immense lake, which, overflowing, penetrated to a branch of the River Kudako, and ran out to sea. Ten years ago there were twenty-two wells and tubes in operation, producing four thousand tons annually. Except for Baku, this section would probably have undergone considerable development, but while crude petroleum can be delivered at the Baku railway station for transportation to Batoum for a *few pence the ton*, it will not pay to exploit the oil in the rocky, woody, roadless region of Kuban. The next most important oil region going east towards Baku is in the Ter and Tiflis districts, where oil has been used for ages, and is found in great abundance. It is quite unnecessary to multiply descriptions of other localities, as at present the oil interests of Russia are centered at Baku. This place has within a few years been connected with Batoum on the Black Sea by a railroad called the Trans-Caucasian Railway. The two places are distant from each other about seven hundred and fifty miles. The road was specially built to accommodate the oil traffic, and places the hitherto almost inaccessible town of Baku in close connection with the Russian system of railways and with the rest of Western Europe. At this place, which is situated on the Apsheron Peninsula, jutting out into the Caspian Sea, the oil belt, instead of being ten miles in width, extends from the mouth of the Samur River at the north of the peninsula to the mouth of the Kura River on the south, a distance of two hundred miles, and the whole of this region may be regarded as oil-pro-

ducing country. "In this manner the entire chain of the Caucasus, seven hundred and twenty miles long, possesses petroleum scattered for the most part sporadically over the surface of the interior, but welling up in vast quantities at the two extremities—the Taman Peninsula in the Black Sea and the Apsheron Peninsula in the Caspian. Between these two points the oil is found at an altitude of nine thousand feet above the sea level and six hundred feet below it." The fact has been stated before that this oil belt follows the mountain, or elevated ridge, beneath the waters of the Caspian Sea. The "Holy Island," which forms the highest point of this ridge, and which emerges from the sea a few miles from the extremity of the peninsula, abounds with petroleum and at one time the Persians gathered it here. Its name also clearly indicates that the ancient fire-worshippers held it as sacred soil and built their altars there. Tcheleken, or Naphtha Island, forming part of the same range, lies near the eastern coast of the Caspian, and is said to be "literally a soddened mass of petroleum and ozocerite." Going still further east on the trend of this belt, in the region of the Balkan Hills, extraordinary deposits of petroleum are found. The existence of oil in this section, however, has been long known. The richness of the deposits here aroused the cupidity of our Baku oil men, an instance of which Mr. Marvin gives in the following language: "In 1881 a party of Russian engineers, while searching for water for the new railway, suddenly alighted upon the 'Naphtha Hill,' when they became aware of the value of what the Duke of Argyll used to designate

her barren and costly acquisitions. This hill lies sixteen and a half miles southwest of the Tageer wells and fifty-three from the railway, with which it is connected by a Decauville miniature railroad. Shortly after it was discovered, a Baku oil exploiter—Prince Yeristoff—quietly staked the whole property as his own, and began to make preparations for working it. The governor of the Trans-Caspian region, General Röhrberg, however, heard of this annexation and sent a geological engineer to the spot to survey it, when an estimate was made, that the ozocerite and oil in the hill thus coolly appropriated were worth £35,000,000 sterling. Upon the receipt of this news, the governor had Yeristoff's stakes pulled up, and the Decauville Railroad removed from Bami to the spot, so as to enable the locomotives to obtain their own supply of petroleum fuel from the locality instead of importing from Baku. At present, there is only one well bored, giving ten tons of petroleum daily, which is amply sufficient for the wants of the railway. Konshin, the mining engineer in charge, reported last year that there were 20,000 acres of petroleum land round about the hill, which could easily furnish 1,000,000 tons of oil annually, that is to say, enough to light every lamp, grease every machine, and drive every locomotive in the Russian empire." From this "Black California," as it has been called, Central Asia will in all probability draw her supplies of light and fuel. In her onward march to India, Russia will be greatly aided by this source of wealth.

Baku Oil District.

The Apsheron Peninsula, upon which Baku is situated, juts out into the Caspian Sea about sixty or seventy miles. The wells which are a few miles west of Baku, are sufficiently elevated above the harbor and the refineries, which are situated just outside of the limits of the city, to allow of the oil finding its way by gravity to these points. There are about four hundred producing wells on the Apsheron Peninsula, collected close together on a space not more than three miles square. This occasions inconvenient crowding, but such is the abundant supply of this plateau, and so certain are the chances of finding oil here, that there exists no temptation to exploit elsewhere, especially when the price is 3*d*. or 4*d*. *per ton*. The deepest well yet sunk in this locality is only about 825 feet, while oil is often reached in paying quantity at the depth of 100 feet. From explorations which have already been made, this peninsula, embracing an area of 1200 square miles, is oil bearing throughout its whole extent, of which only three square miles are non-producing. From this small part already 4,000,000 tons, or 30,476,190 barrels of 42 gallons each, have been produced.

The statement concerning the enormous yield from some of the wells of this district may well challenge our credulity. The following graphic description of the bursting forth of the great Droojba fountain is from an eye-witness, and is given in Mr. Marvin's own words: "In America there are over 25,000 drilled petroleum wells;

Baku possesses 400, but a single one of those 400 wells has thrown up as much oil in a day as nearly the whole of the 25,000 in America put together. This is very wonderful; but a more striking fact is that the copiousness of the well should have ruined its owners, and broken the heart of the engineer who bored it, after having yielded enough oil in four months to have realized in America at least one million sterling. 'In Pennsylvania that fountain would have made its owner's fortune; there is £11,000 worth of oil flowing out of the well every day; here it has made the owner a bankrupt.' These words were addressed to me by an American petroleum engineer, as I stood alongside of a well that had burst the previous morning, and out of which the oil was flying twice the height of the Great Geyser in Iceland, with a roar that could be heard several miles round. The fountain was a splendid spectacle, it was the largest ever known at Baku. When the first outburst took place the oil had knocked off the roof and part of the sides of the derrick, but there was a beam left at the top, against which the oil broke with a roar in its upward course, and which served in a measure to check its velocity. The derrick itself was seventy feet high, and the oil and the sand after bursting through the roof and sides flowed fully three times higher, forming a grayish-black fountain, the column clearly defined on the southern side, but merging into a cloud of spray thirty yards broad on the other. A strong southerly wind enabled us to approach within a few yards of the crater on the former side, and to look down into the sandy

basin formed around about the bottom of the derrick, where the oil was bubbling and seething round the stalk of the oil-shoot like a geyser. The diameter of the tube up which the oil was rushing was 10 inches. On issuing from this the fountain formed a clearly defined stem about 18 inches thick, and shot up to the top of the derrick, where in striking against the beam, which was already half-worn through by the friction, it got broadened out a little. Thence continuing its course, more than 200 feet high, it curled over and fell in a dense cloud to the ground on the north side, formed a sand bank, over which the olive-colored oil ran in innumerable channels towards the lakes of petroleum that had been formed on the surrounding estates. Now and again the sand flowing up with the oil would obstruct the pipe, or a stone would clog the course; then the column would sink for a few seconds lower than 200 feet, to rise directly afterwards with a burst and a roar to 300 feet. . . . Some idea of the mass of matter thrown up from the well could be formed by a glance at the damage done on the south side in twenty-four hours; a vast shoal of sand having been formed which had buried to the roof some magazines and shops, and had blocked to the height of six or seven feet all the neighboring derricks within a distance of fifty yards. . . . Standing on the top of the sand shoal we could see where the oil, after flowing through a score of channels from the ooze, formed in the distance or lower ground a whole series of oil lakes, some broad enough and deep enough to row a boat in. Beyond this the oil could

be seen flowing away in a broad channel towards the sea. This celebrated well, from the best estimates that could be made, gushed forth its oil treasure at the rate of 'two million gallons per day' from a depth of 574 feet. A remarkable fact is also stated, that, notwithstanding these 400 wells are so closely situated to each other, there appears to be no connection with the subterranean reservoirs which supply the oil.

"Near the village of Strikhoff, at Bibi Aibat, a short time ago, there were four wells giving oil within a few yards of one another; yet all at different depths, the first at 259 feet, the second at 560, the third at 280 feet, and the fourth at 350. Close to them was a more striking instance: An old well existed 70 feet deep, which for generations had furnished petroleum. The engineers set up a derrick a few yards from it, expecting to get oil readily at about the same depth, but did not strike any until they had penetrated 420 feet. If the oil were collected in a single reservoir, or in basins joined to one another, it is obvious that the fountains that often occur would exhaust the surrounding localities. The Droojba fountain, for example, which I saw spouting oil at the rate of two million gallons per diem, would have ruined all the neighboring wells of a lesser depth had the reservoir been a general one. As a matter of fact, while it was shooting its oil 300 feet high, the wells a stone's throw off were giving their daily supply of petroleum, totally unaffected by it. Many pumping wells have been worked for years without the level of the oil being lowered in the

slightest degree, or the wells in any way affected by discharges from adjoining fountains proceeding from greater or lesser depths. The peninsula of Apsheron is probably honeycombed with thousands of oil-cells. One of these cells, belonging to Kokereff, has already given a million and a half of barrels of oil, and yet the pump draws the oil as freely and as readily to the surface as when the basin was first tapped by the boring bit years ago."

From the records which have been kept, it appears that from the deepest wells have issued the most oil. As a general rule, the borer begins to look for appearances of oil at or about the depth of a hundred feet; if it is reached at that depth in paying quantities, it is allowed to flow or it is pumped until it is exhausted. The engineer then begins to bore again until another oil cell is reached; this process is continued until a more copious supply is reached which is expected to last for years. In 1883 two flowing wells in less than a month upheaved nearly 30,000,000 gallons of oil apiece from a depth of 700 feet, and when they were plugged to preserve their supply for future use, they were still flowing at a rate of about 20,000 gallons of oil per diem.

That the supply of petroleum in this district is enormous is beyond all controversy. It is not questioned by any who have personally inspected it.

The oil is brought from the wells eight or nine miles distant to the refineries which are at Black Town, a short distance outside of Baku, by a number of pipe-line companies, the largest of which is that of the Nobel Brothers,

which has the capacity of delivering 4,000,000 gallons annually to their refineries.

To further illustrate the enormous yield from these wells it may be proper to notice the accounts given of some of the larger wells. Many of the largest have been plugged up to prevent actual waste. Nobel Brothers have thus closed fourteen of their wells, and wait for a rise in the price of oil. One of these ejected 112,000 tons during the first four weeks before it was sealed up. In 1875, the third flowing well in this district was struck, bringing to its owners 600,000 gallons per diem. The following year the same company (The Company of Petroleum Participators) struck another flowing well. At the depth of 280 feet, through an iron pipe of 6½ inches in diameter, the oil was thrown up with great force, and continued to flow at the rate of 270,000 gallons daily for three months.

In 1877, another concern, the Orbelovi Brothers, obtained a flowing well at the depth of 210 feet, with a bore of 10½ inches, which proved to be one of the largest in this district. The oil spouted slightly a few days and was then capped, but in making some improvements afterwards to cap, the pressure below burst it off the tube, and the petroleum issued with a fury nothing could check. In half an hour a reservoir, holding 40,000 gallons was filled, and then the oil ran all over the place, forming a series of lakes. This fountain never spouted less than 40,000 gallons per day, and sometimes reached 1,200,000 gallons. It was estimated that forty million gallons of oil were lost before this "gusher" was subdued. As an instance, both

of an abundant and persistent yield, may be cited "Meerzoeff's No. 5 in Group IX." This well was bored in 1876 to the depth of 340 feet; the oil began to "spout" at the rate of 80,000 gallons daily; gravity 0.865. After a while the well was capped and the flow regulated. It has continued to flow ever since, and had furnished to its owners up to the end of 1883 16,000,000 gallons. In 1882 "The Company of Petroleum Participators" had a fountain at their No. 9 well from a depth of 476 feet. The tube was 10 inches in diameter. Its greatest outflow lasted twenty days, during which time it brought to the surface 8,000,000 gallons. The average yield was 400,000 gallons per day. Of this yield 1,600,000 gallons were sold, 1,200,000 gallons conducted to a depression and stored, and 5,200,000 gallons were lost. A cap was fixed on the sixth day, and the well has since proved one of the most productive at Balakhani. Mr. Marvin has carefully secured the details of a large number of wells. Without wishing, however, to multiply instances of the exceeding productiveness of this territory, we will conclude with the mention of Nobel's No. 9 well. This remarkable fountain sent forth its treasured wealth from a depth of 642 feet, producing 30,000,000 gallons in four weeks. The height of the fountain was 200 feet, and it threw the oil and sand for a distance of 200 feet round about the derrick. Owing to the ample means and extensive preparations made by the company, only 1,000,000 gallons out of the 30,000,000 gallons were lost. After the pressure in the well had fallen so that the orifice could be conveniently plugged sufficiently

tight to resist the force below, the delivery of the oil was still at the rate of 600 barrels per hour. Another fountain at their No. 25 well threw up nearly two million gallons of oil daily from a depth of 582 feet. The pressure on the tube was 200 pounds to the square inch. This well was yielding at the time of Mr. Marvin's visit one million gallons crude oil per diem.

As it will be readily supposed, the immense yield of such a flowing well as the Droojba would seriously affect prices. At one time the effect was such, in the absence of any local demand, as almost to deprive it of any value. A certain refiner filled his reservoirs from this celebrated well while it was flowing largely, with 2,800,000 gallons for 300 roubles, or £30. Thousands of tons were burnt outside the district to get rid of it, and thousands were led towards the Caspian Sea and thus disposed of. It is not to be wondered that such a waste of valuable material should have aroused the indignation of the more thoughtful miners. A congress of the well owners was called to find out some plan to plug up the irrepressible Droojba. The Government at St. Petersburg was appealed to, which responded with an appropriation of 2000 roubles to send a couple of engineers to the spot. It was finally "capped" on the 29th of December, and its flow regulated by a valve arrangement, after having flowed for a period of five months at an average rate of a little over 25,000 barrels of 42 gallons per diem. Such a flow of oil has no parallel, and to prevent the culpable waste such as has already occurred,

any method, even confiscation of the property by the Government, would be justifiable.

There are about 200 petroleum refineries in operation at Black Town, a short distance from Baku. The largest of these are owned by the Nobel Brothers, and have a capacity to turn out fifty thousand barrels refined oil per day. These works are admirably arranged and most skilfully conducted. The cleanliness, system, and good order observed are quite in contrast with what prevails in most of the others. It is said that this concern turns out yearly more than all the others combined. The growth of the refining business has steadily increased, as the following table will show:—

1872.	Refined product	16,400 tons.
1873.	" "	24,500 "
1874.	" "	23,600 "
1875.	" "	32,600 "
1876.	" "	57,100 "
1877.	" "	77,600 "
1878.	" "	97,500 "
1879.	" "	110,000 "
1880.	" "	150,000 "
1881.	" "	183,000 "
1882.	" "	202,000 "
1883.	" "	206,000 "

The usual gravity of Russian refined petroleum is 0.822, with a flashing point, determined by the English test, (Abel's) of 32° Celsius or 90° Fah.

Crude Russian petroleum is much heavier than the American product, and the percentage yield of illuminating oil much less. There are, however, some varieties from

certain wells much lighter than others. The subjoined table furnishes valuable information as to its density, composition, and heating capacity. These figures are furfurnished by Gospodin Gulishambaroff:—

	Specific gravity.	Carbon.	Hydrogen.	Oxygen.	Heating power.
Russian light oil	0.884	86.3	13.6	0.1	22628 B. U.
" heavy oil	0.938	86.6	12.3	1.1	19440 "

Mr. Ludwig Nobel has furnished the following as an average assay of Russian oil, showing the yield of the different refined products. From this it will be noticed that the yield of illuminating oil is only about one-third of that obtained from American petroleum, while the yield of lubricating oils of the various qualities is much larger. This large difference in the percentage of illuminating oil obtained from the two varieties of American and Russian petroleum is more than compensated for in the enormous production of the latter, while there is still to be added the larger product of valuable lubricating oils.

100 gallons crude oil.	Gallons.	Gravity.	Flashing point.
Benzene, light oil . . .	1	0.725	— 10° Cel.
Gasolene, " . . .	3	0.775	+ 0 "
Kerosene, illuminating oil . .	27	0.822	25° "
Soliarovi, lubricating oil . .	12	0.870	100° "
Veregenni, " " . .	10	0.890	150° "
Lubricating oil	17	0.905	175° "
Cylinder, lubricating oil . .	5	0.915	200° "
Vaseline	1	0.925	
Residuum (liquid fuel) . .	14		
Loss	10		

It is stated upon what appears to be the best authority, that, notwithstanding the greater density of the Russian refined oil, it has the very desirable peculiarity of ascending the wick of the lamp while burning much more readily than the lighter American oil. The fact has often been noticed, that after the fountain in the ordinary lamp filled with many samples of American oil has become half exhausted, there is a marked decrease both in the size of the flame and the brilliancy of the light. The usual expedient adopted to remedy this difficulty is to give the reservoir a flattened shape, thus decreasing the height to which the oil must ascend before it is ignited. A very careful examination of the respective merits of these two varieties of oil has been recently made by Mr. Boverton Redwood, Chemist to the London Petroleum Association. In the report of this examination he says: "In color and odor the oil compares favorably with the ordinary oil refined in the United States, the color being in fact but little darker than that of many parcels of, so-called, water-white American petroleum. The flashing point usually ranges from 86 to 88 degrees Fah. (Abel test), which is considerably higher than that of the ordinary American oil. The high specific gravity (in some cases as much as 0.822). is a characteristic feature of the product, and, arguing from experience gained in relation to American petroleum, it has been erroneously asserted that such oil would require a special form of lamp for its satisfactory consumption. These experiments were, therefore, directed to the determination of the burning quality of the oil in such lamps as are commonly used in this country.

As a preliminary step, the oil was first tested roughly by burning it for lengthened periods in various forms of lamps, both cheap and costly, including those with single flat wicks, two parallel flat wicks (Duplex), and circular wicks (Argand). No difficulty was experienced in obtaining a flame of good size and character in each form of lamp, and the flame preserved those features until the whole of the oil contained in the lamp reservoir had been consumed. Ordinary American oil in fact exhibited marked inferiority to the Russian oil in the size of the flame after some hours' burning, the most noticeable features being, that the Russian oil was consumed with remarkably little diminution in the size and illuminating power of the flame, and that the wick exhibited a very small amount of charring. To the unaided eye of the ordinary observer there was, on the whole, little if any difference in the light-giving power of similar lamps charged with Russian and American oil respectively, burning side by side. The practised eye could, however, with some of the lamps, detect somewhat less brilliancy in the flame of the Russian oil during the earlier hours of the burning, but at a later period, when much of the oil had been consumed, these conditions became reversed. In the cheap form of lamp with a single flat wick, so largely used by the poorer classes, constituting the bulk of the consumers, the Russian oil gave on an average the same amount of light as was yielded by the American oil. The following is a summary of his conclusions:—

1. The Russian oil possesses advantages over the ordi-

nary American petroleum oil of commerce in respect to color and odor.

2. Although the photometer indicated that the ordinary American oil is capable of yielding in the test-lamp a greater amount of light irrespective of the quantity of oil burned (especially when the lamp has been recently filled and trimmed) than the Russian oil affords in the same lamp; yet the latter gives (*A*) what the consumer would call a good light not only at first, but also after several hours' burning, and actually furnishes (*B*) more light per gallon of oil burned than is afforded in the combustion, under similar circumstances, of three out of five samples of ordinary American oil examined, and (*C*) but little less light than is yielded by an equal quantity of the American water-white oil tested.

If the Russian crude petroleum yields a smaller percentage of illuminating oil than the American variety, it affords a much larger quantity of lubricating oil and that of a very superior kind. It has been stated "that it throws the American article completely in the shade." It is represented as highly "viscous," and will stand a much lower "cold test." At present, only the larger refineries, such as the Nobel Brothers, Meerzoeff Sons, and a few others, are, to any extent, engaged in the production of lubricating oils. These are, however, exporting considerable to Europe by way of Batoum and Libau. Besides this, large quantities of the heavy oil left in the still after the separation of the illuminating oils, constituting perhaps 60 per cent. of the whole product, is sent in the same direction, in a crude state to

be manufactured into lubricating oils. It is said that the Messrs. Nobel Brothers annually turn out 27,000 tons of finished lubricating oils of different kinds.

In the matter of lubricating oils, with quality and price both in favor of the Russian oils, it is not a difficult matter to predict in the competitive race for supremacy which shall ultimately carry off the palm.

Russian Liquid Fuel.

Under the name of "liquid fuel," the heavy residual oil (left in the still after the burning oil has been taken off, and constituting, as has just been stated, about 60 per cent. of the original "charge") is very extensively employed under the furnaces of the steamers and locomotives all through the Caspian region. While Western Europe and the United States have been experimenting and devising all manner of petroleum furnaces, the problem has been satisfactorily solved in the Caspian basin. As intimated before, this local success is not due to any great superiority of the inventions themselves, but simply to the fact, that, in this particular locality, the abundance of petroleum and the comparative scarcity of coal have jointly contributed to stimulate inventions, having in view the consumption of petroleum as fuel. Hence great attention has been given to the subject. Engineers of the highest skill and reputation have devoted much time to improving and devising apparatus for the convenient consumption of the heavy oil as a fuel. Their efforts have been eminently

successful, and now this "liquid fuel" is the only fuel used in this section. It has entirely replaced wood and coal in all the steamers plying on the Caspian Sea, and on the Trans-Caucasian Railroad, and in the furnaces and factories of that section. Its use has extended as far north as Moscow, to Teheran to the south, to Merv and Khiva to the east, and to Batoum to the west. Baku at present is the Newcastle of the Caspian. Ere long, as soon as the railroad connections are made, the Black Sea steamers will find it far more economical to use it than English coal, and thus there will be diverted from its accustomed channel another large branch of business. The estimated production of this "liquid fuel" at Baku, placing it at the lowest figure, is about half a million tons annually. In 1883, the export of this refuse heavy oil from Baku to various parts of Russia was 281,000 tons; "leaving, after making allowance for home consumption, perhaps 200,000 tons undisposed of." "During the last ten years," Mr. Marvin states, that "countless millions of gallons have been wasted," and "owing to this glut, the price for years has fluctuated between a few pence and half a crown a ton, varying according to the demand and the distance of the product from the coast.

"During the last few months Nobel Brothers have completed the organization of this refining, and for the future expect to turn out oil-refuse at the rate of 1300 tons per day, or 450,000 tons in the course of a year. As, in a good hydro-carbon furnace, one ton of liquid fuel goes as far as three tons of mineral fuel, it follows that this single

establishment alone will produce annually the equivalent of 1,350,000 tons of coal."

In a section of country where coal sometimes sells for as much as $25 per ton, figures like the above carry with them the prediction of great changes in trade centres.

We consider it quite unnecessary in this connection to devote any space to the description of the peculiarities of the petroleum furnaces employed either on the *Caspian steamers* or on the locomotives in that vicinity. It would doubtless be interesting to the mechanical engineer, who is interested in this particular branch of science, but as full details of these various devices with specifications and drawings may be obtained from the department of patents, of Russia, it may be omitted.

The advantages claimed for the use of this liquid fuel are: 1. Convenience and speed in loading a supply of fuel upon a steamer or locomotive. 2. A saving of space of from one-half to two-thirds in the hold of the vessel, which may be appropriated to additional freight. 3. A large saving of labor in "stoking." 4. An immense saving of expense in the difference in the cost between the prices of coal and liquid fuel. It is estimated that Russia imports yearly into the Black Sea about 300,000 tons of coal, chiefly from England, the price of which ranges from £2 to £3 a ton. Experiments have been recently conducted by the Russian government, at Sevastopol, looking to the introduction of liquid fuel for the Black Sea fleet, and when pipe lines have been laid from Baku to Batoum on the Black Sea, its extension to the Mediterranean will soon

follow. Mr. Marvin, in summing up the advantages of liquid fuel, makes the following statement: "A ton of liquid fuel can do the work of two or three tons of coal. Thus a steamer can either take two or three times less fuel and utilize the bunker space for cargo purposes, or it can go two or three times as far without stopping to coal. But there is an additional economy beyond even this. A ton of oil-refuse, I believe, takes up very little more than half the space of a ton of coal. In this manner in the more economical liquid-fuel furnaces, 1000 tons of oil-refuse not only goes as far as 3000 tons of coal, but takes up only the bunker space of 500 or 600 tons of coal and allows the balance of 2500 tons to be applied to passenger or cargo purposes. General Valentine Baker and Mr. Arthur Arnold, M. P., who have examined the petroleum-burning steamers of the Caspian, speak in the warmest terms of the advantages of liquid fuel. In America, there has not yet been anything like the development observable in the Caspian, and the use of the fuel is still in a crude experimental stage. The following are the advantages claimed by Chief Engineer Isherwood of the United States Navy for liquid over solid fuel: 1. Reduction of 40.5 per cent. in weight of fuel. 2. Reduction of 36.5 per cent. in bulk. 3. Greater facilities in storage. 4. Reduction of number of stokers to one-quarter. 5. Greater speed in raising steam. 6. Fires can be extinguished instantly. 7. No smoke, no ashes, no waste. 8. No loss of heat from opening furnaces to feed with coal. 9. Ability to command increased temperature without forced draught."

In connection with the Russian petroleum industry a brief description of the operations of the Nobel Brothers seems appropriate. They control a capital of nearly eight millions of dollars, paying an average dividend of 20 per cent. At the oil fields of Balakhani they have over forty wells, of which fourteen are "fountains." One of the latter yielded in 1883, 112,000 tons of crude oil in a month. They possess two pipe lines each eight miles long, and capable of conveying 4,000,000 barrels yearly, which lines connect their wells with their refinery at Black Town, Baku. The refinery covers more than a mile square of ground, and is able to turn out daily in the busy season 220,000 gallons of illuminating oil, 80 tons of lubricating oil, and 1300 tons of liquid fuel, equal to a yearly production of 65,000,000 gallons of illuminating oil, 27,000 tons of lubricating oil, and 450,000 tons of liquid fuel. Each of its large refuse reservoirs holds 4,000,000 gallons of liquid full at a time. On the Caspian Sea, the firm has twelve large cistern steamers, costing over a million and a quarter dollars; twelve steamers and forty barges on the Volga River, and a dock yard at Astrakhan, costing nearly one million dollars. At Tsaritzin and twenty-six other points in Russia, they have established depôts for 35,000,000 gallons of illuminating oil, and have placed on different railways in Russia 1500 tank cars. Altogether their organization gives employment to not less than 5000 people, and at times this has been raised to double the number. These statistics represent a growth of less than ten years.

A late and exhaustive view of the Baku petroleum industry is included in a volume, this year (1886), issued by

the British Foreign Office. It is found in the report of Mr. D. L. Peacock, the British Vice-Consul at Batoum. After tracing the great development of the industry since the abolition of the monopoly in 1873, and of the excise duty in 1877, Mr. Peacock goes on to state that, notwithstanding the immense natural riches of the district, the producers and traders have been laboring under exceptional pecuniary difficulties during the past few years, these being the natural result of the wild "rush," a few years ago, of people of all classes, to the Baku petroleum regions, when it was generally believed that in a short space of time American petroleum would be driven out of the European markets by the Russian product. These sangnine expectations were not realized, and hence the depression which has since prevailed. The American producers were not so easily put down, since, for a long time, they had ruled the petroleum trade in Europe, and possessed perfectly organized connections, together with great financial means. In the last two respects, Russia was at a great disadvantage. The opening of the Trans-Caucasian Railway failed to bring to the Baku producers and traders the benefits anticipated, and the carrying capacity of the line proved to be inadequate. The commercial organization of the whole business was also defective. As a consequence, prices went down, and profits became rare exceptions. Competition increased, and, owing to the actually hostile relations between the few large firms and the multitude of small refiners, affairs rapidly went from bad to worse. Affairs at last became so bad, that the government was

asked to sanction a conference in order to devise some means of effecting an improvement. Accordingly, by an Imperial Order made in February, 1884, regular conferences were instituted at Baku, at which all the petroleum interests were represented, and special delegates also attended on behalf of the government. These conferences, of which three have been held, were not invested with any legislative or executive power, since all resolutions passed had to be submitted to the Russian government.

The first conference that was held led to an increase of accommodation on the Trans-Caucasian Railway, and at the Port of Batoum, etc. And, it is also owing to the suggestions of this conference that a variety of improvements have been applied in drilling and refining operations, and partly in the general management of the business; the checking and controlling of destructive and wasteful flowing wells by means of valve-caps; the lowering of railway rates and of freights by special conventions between shipping and railway companies, etc. The second conference, held in the spring of 1885, was an utter failure in every respect. The proceedings have never been pub lished, and the practical results were actually *nil.* At the third conference, held in the spring of this year, a number of questions were discussed, and some resolutions were passed. Of the latter, the most important were: one, to the effect that it is desirable that a bank should be established, on terms of reciprocal credit, for the special use of people connected with the petroleum industry and trade, and that, in the meanwhile, the local government

bank should be authorized to issue loans on securities of petroleum products in stock, and to advance money against bills of lading, railway quittances, etc., and another referring especially to an increase in facilities on the Trans-Caucasian Railway. But neither of these is thought likely by Mr. Peacock to produce much good. He points out that during the last two years means of transport have almost doubled, and railway rates and freights on the Caspian and Black Sea have been considerably reduced, but that at the same time prices at the oil fields have fallen, and sales are only made at a loss. As to the extension of credit, he says that "the opening of additional and cheaper credit would almost certainly lead to increase of production, just the thing that could not but prove finally ruinous to producers and traders. As it is, operations are being conducted, not on commercial principles, but on the theory of chances and gambling—and this is not what justifies any claim to credit. In the course of the last ten years Baku has been largely supplied with capital, locally, as well as from Russia and European money markets, and, in former years, considerable profits were derived from the petroleum trade, and it was scarcely observed for some time that the majority of drillers and refiners were fatally drifting towards a crisis, but it is now admitted that they are on the brink of insolvency. The misfortune is ascribed to a great extent to want of cash, accompanied by stringency of credit, which, in fact, is but the effect, not the cause, of the anomalous conditions and unprofitableness of the petroleum trade in its present state

of development. The chief remedy for the present condition is considered by Mr. Peacock to be the construction of a pipe line from Baku to some point on the Black Sea coast, for the transportation of crude oil. By this means it is thought that the yield of crude oil, which is much more than can be properly dealt with at Baku, may be profitably turned to account. Despite the present opposition to the scheme on the part of those interested in the transport of oil from Baku, Mr. Peacock thinks that such a pipe line will have to be laid down in the near future. Another thing likely to affect the Baku oil industry is the probable transfer of many of the present works from their present almost bankrupt proprietors to wealthy firms. Already, in fact, the property and works of the Caspian and Black Sea Petroleum Company—one of the largest firms in the trade—have been acquired by the Messrs. Rothschild, of Paris.

In regard to the production of petroleum at and around Baku, the following figures are given, which show the quantities exported from Baku by the Trans-Caucasian Railway and by the Caspian, to Russian and foreign markets:—

	1885. Gallons.	1884. Gallons.	1883. Gallons.
Kerosene . . .	137,000,000	109,000,000	72,000,000
Crude oil . . .	19,000,000	10,000,000	10,000,000
Residue . . .	170,500,000	142,800,000	87,000,000
Lubricating oil . .	7,950,000	7,200,000	5,000,000
Benzine . . .	140,000	380,100	240,000
Total . . .	334,590,000	269,380,100	174,240,000

The production in 1885 was obtained from about 160 wells. These are all that are productive out of about 500 sunk since 1873. Of these, 170 are now utterly exhausted; 60 are abandoned on account of technical or financial difficulties; about 40 are being kept idle for want of demand for crude oil; and 70 are not yet completed. There are 136 refineries, of which twelve of the largest are furnished with 216 stills, of a capacity of 750,000 gallons, and are producing yearly 125,000,000 gallons of kerosene; while the 124 small refineries have 325 stills, of a capacity of 475,000 gallons, and produce yearly about 15,000,000 gallons of kerosene. Owing to low prices, 40 of the above-mentioned small refineries have entirely stopped operations, and at a great many others, not excepting large ones, work has for the same reason being partly suspended. It is estimated that by using the actual working capacity, taking 300 working days, the twelve large refineries are prepared to turn out yearly 200,000,000 gallons, and the 124 small refineries 125,000,000 gallons of kerosene. The refining of lubricating oil is much less extensive, and is in the hands of but a very few firms. The total production of lubricating oil in 1885 was about 8,000,000 gallons. This enormous increase in the production shown above has not been accompanied by any corresponding extension in the area of the territory where drilling operations are being carried on. Going back, in fact, to 1876, although more than 300 wells have been bored, and the yearly production has increased from 30,000,000 gallons to 575,000,000 gallons, the oil district

has been confined to a distance of from three to nine miles from Baku, having a total area not exceeding 1200 acres.

No serious efforts, Mr. Peacock says, have been yet made to extend drilling operations to new territories, nor does there seem to be any pressing necessity for doing so, considering the more than sufficient yield of petroleum on the ground actually occupied. For the sake of speculation rather than from commercial necessity, some wells have been sunk in localities at a more or less considerable distance from the old territories without leading to any practical results, but a few desultory wells sunk at random can scarcely serve as a criterion of the potential capacity of new territories. It cannot be doubted that there are other tracts of oil-bearing territories in addition to those already known as productive, and that, when the necessity presents itself, such tracts are sure to be found along the coast of the Caspian, on a broken line of about sixty miles, stretching from Besh-Permak to Aliata, and intersecting the Peninsula of Apsheron. But it is important to notice that, for the present, the Russian petroleum trade depends entirely on the above-mentioned old territories of a very limited area. The repeatedly-tested petroleum region of the Koubàn yields scarcely 1 per cent. of what the total production of Baku amounts to; and as to the much-boasted petroleum riches of the Trans-Caspian deserts, it must be said that the, apparently, most promising part of that territory, the Nephtenaga Gora (Petroleum Mountain), some eighteen miles from the station Balla-Ishem,

gives but a few hundred gallons of crude oil per day. Again, with regard to the future, the fact should not be ignored that at Baku the level of the subterranean petroleum deposits is steadily lowering at the rate of about 5 feet for every 50,000,000 gallons of crude oil extracted.

Although present prices at Baku leave no profit to the refiners, the cost of production is said to be very low. The highest price of crude oil at the wells is 1 copeck per poud, or less than a farthing for five gallons, which is said to safely cover the cost of production. Refined oil costs the refiners about 9½ copecks per poud, or about *2d.* for 5 gallons, exclusive of wear and tear of plant, expenses of management, and the very heavy interest upon the capital invested. These, but especially the latter, together with the inordinate charges for storage of oil, and the expensive and insufficient railway facilities, suffice to heavily handicap the Russian producers in the European markets. Nevertheless, these difficulties will no doubt be overcome, sooner or later.

CHAPTER V.

THE ORIGIN AND RAPID GROWTH OF THE PETROLEUM INDUSTRY IN THE UNITED STATES.

WHEN it is stated that within the memory of comparatively young men, petroleum, from being an article of curiosity upon the shelves of the laboratory, has advanced to be an item of export rating fourth in commercial prominence in this country, we may form some idea both of its pecuniary value and the marvellous rapidity with which it has assumed such proportions. A number of circumstances have contributed to this rapid growth. A rapidly increasing population with its proportionately growing demand for illuminating materials, tended constantly to such an advancement in their price as greatly to restrict their use. This threatened serious inconvenience to the average consumer and also the entire extinction of the whale species, which at one time furnished the chief supply. The next link is furnished by the introduction of the hydro-carbon oils, distilled from bituminous shale. This, more than anything else, prepared the way for the introduction of petroleum, although we have at hand authentic data connecting mercantile transactions in petroleum in a small way, with the very early settlement of Western Pennsylvania.

From the existence of the remains of certain curiously contrived pits lined with roughly hewn logs, in the oil-pro-

ducing region of Pennsylvania, along the borders of Oil Creek, and other small streams, it has been, we think, very correctly surmised, that the Indians of that locality at a very early date, perhaps long before the discovery of America by the white race, both knew of the existence of this oil and, in their crude way, gathered it for their own use. The methods employed by the aborigines of this country in collecting what is usually called "surface oil" did not differ materially from those resorted to by the natives of other countries, and which are still used in many places. The plan is simply to dig a well or pit, which is usually lined with boards or logs to prevent the sides from caving-in. Both water and oil usually flow into the excavation together, the oil rises to the surface and is skimmed off in some instances, in others, as among the Indians, cloths or blankets were carefully laid upon the surface of the oil in order to absorb it; these were subsequently "wrung out" and the oil collected in vessels. When the white man appeared it was found that the natives had already discovered some of its valuable properties as a medicine; it was used by them both internally, for a variety of complaints, and externally, as a remedy in skin diseases. It was employed as an illuminant in a crude way and as a vehicle for mixing paints. It was also employed by them in their worship of the Great Spirit, and when they needed to give great éclat to their religious ceremonial, it was customary to set fire to the oil floating upon the surface of the water. We find in another section of the globe, on the borders of the Caspian Sea, the same, or a similar custom, derived in this instance

from the ancient fire-worshippers. During the early part of the present century the repute which petroleum had attained as a medicine among the aborigines had spread among the white settlers, and considerable quantities were sold under the name of "Seneca oil," under which name it may be still found upon the druggists' shelves, and is sold, we presume, at its former high price. Petroleum is also the chief ingredient of a still popular medicine known as "Harlem oil." That it possesses useful remedial properties there is abundant evidence, and it has a recognized place in the *Materia Medica* of the United States. It is supposed to possess medical properties both as an external and internal remedy in rheumatism, sprains, bruises, etc., and internally in diseases of the lungs and urinary organs. It is also anti-spasmodic.

The French commander at Fort Du Quesne, in the year 1750, wrote to General Montcalm describing the most astonishing natural wonders of the country, and mentions the oil streams to which they were invited by the chief of the Senecas, to attend a religious ceremony of the tribe. We are, however, indebted for the first reliable scientific record of the discovery of petroleum in this country to Professor Benjamin Silliman, the Elder, who contributed to the 'American Journal of Science' in the year 1833, the following account of—

"*A Fountain of Petroleum*, called the oil spring. This is situated in the western part of the county of Allegany, in the State of New York. This county is the third from Lake Erie on the south line of the State, the counties of

Cattaraugus and Chautauqua lying west and forming the southwestern termination of the State of New York. The spring is very near the line which divides Allegany and Cattaraugus. . . . The country is rather mountainous, but the road running between the ridges is very good, and leads through a cultivated region, rich in soil and picturesque in scenery. Its geological formation is the same with that which is known to prevail in the western region, a silicious sandstone with shale, and in some places limestone is the immediate basis of the country. The sandstone and shale (the limestone I did not see) lie in nearly horizontal strata. The sandstone is usually of a light gray color, and both it and the shale abound with entrocites, encrinites, coralines, terebratula, and other *reliquiæ* characteristic of the secondary transition formation. The oil spring or fountain rises in the midst of a marshy ground. It is a muddy, dirty pool of about eighteen feet in diameter, and is nearly circular in form.

"There is no outlet above ground, no stream flowing from it, and it is of course a stagnant water, with no other circulation than that which springs from the changes of temperature and from the gas and petroleum that are constantly rising on the surface of the pool.

"The water is covered with a thin layer of petroleum or mineral oil, giving it a foul appearance as if coated with dirty molasses, having a yellowish-brown color. Every part of the water was covered by this film, but it had nowhere the iridescence which I recollect to have observed at St. Catharine's Well, a petroleum fountain, near Edinburgh, Scotland. There the water was pellucid, and the hues

produced by the oil were brilliant, giving the whole a beautiful appearance. The difference, however, is easily accounted for. St. Catharine's Well is a lively flowing fountain, and the quantity of petroleum is only sufficient to cover it partially, while there is nothing to soil the stream. In the present instance, the stagnation of the water, the comparative abundance of the petroleum, and the mixture of leaves and sticks, and other productions of a dense forest preclude any beautiful features. There are, however, upon this water, here and there, spots of what seems to be a purer petroleum, probably recently risen, which is free from mixture, and which has a bright brownish-yellow appearance, lively and sparkling. Were the fountain covered entirely with this purer production, it would be beautiful. . . .

"They collect the petroleum by skimming it like cream from a milk-pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon, and just under the surface of, the water, and is soon covered by a coating of petroleum, which is so thick and adhesive, that it does not fall off, but is removed by scraping the instrument upon the lip of a cup. It has then a very foul appearance like very dirty tar or molasses; but it is purified by heating it and straining while hot through flannel or other woollen stuff. It is used by the people of the vicinity for sprains and rheumatism, and for sores upon their horses.

"It is not monopolized by any one, but is carried away freely by all who care to collect it, and for this purpose the

spring is frequently visited. I could not ascertain how much is annually obtained, but the quantity is considerable. It is said to rise more abundantly in hot weather than in cold. Gas is escaping constantly through the water and appears in bubbles upon its surface. It becomes much more abundant, and rises in large volumes whenever the mud at the bottom is stirred with a pole. We had no means of collecting or of firing it, but there can be no doubt that it is the carburetted hydrogen, probably of the lighter kind, but rendered heavier and more odorous by holding a large portion of the petroleum in solution. Whenever it is examined, we should expect of course to find carbonic acid mingled with it, and not improbably nitrogen. We could not learn that any one had attempted to fire the gas as it rises, or to kindle the film of petroleum upon the surface. We were told that an intoxicated Indian had fallen into the pool and been drowned many years ago, but his body had never been recovered. The story may be true, and if true, it would be a curious inquiry, whether the antiseptic properties of petroleum so well exemplified in the Egyptian mummies may not have preserved his body from putrefaction.

"I cannot learn that any considerable part of the large quantity of petroleum used in the Eastern States under the name of 'Seneca oil' comes from the spring now described. I am assured that its source is about one hundred miles from Pittsburgh, on the Oil Creek, which empties into the Allegheny River in the township and county of Venango. It exists there in great abundance, and rises in purity to the

surface of the water. By dams inclosing certain parts of the river or creek it is prevented from flowing away, and is absorbed in blankets from which it is wrung. . . . . And as there are numerous springs of this mineral oil in various regions of the West and South, connected especially with the saline and bituminous coal formations, it would promote the cause of science if notices of any of them were forwarded for publication.

"The petroleum sold under the name of 'Seneca oil' is of a dark brown color, between that of tar and molasses, and its degree of consistency is not dissimilar, according to temperature. Its odor is strong, and too well known to need description. I have frequently distilled it in a glass retort, and the naphtha, which collects in the receiver, is of a light straw color and much lighter, more odorous and inflammable than petroleum. In the first distillation a little water usually rests in the receiver at the bottom of the naphtha. From this it is easily decanted, and a second distillation prepares it perfectly for preserving potassium and sodium, the object which led me to distil it, and these metals I have kept under it, as others have done, for years. Eventually they acquire some oxygen from or through the naphtha, and the exterior portion of the metal returns slowly to the condition of alkali, more rapidly if the stopper is not tight. The petroleum remaining from distillation is thick like pitch. If the distillation has been pushed far the residuum will flow only languidly into the retort, and in cold weather it becomes a soft solid resembling mineral pitch. . . . . In alluding to the probable connection

with bituminous coal of the oil spring named at the head of this notice, I did not mean to imply that petroleum and other bituminous substances necessarily prove that there is coal beneath, for it has been ascertained that bitumen exists in a limited degree in many minerals, as appears from some of the phenomena of volcanoes, and was proved experimentally by the late Hon. George Knox in an extensive series of researches published in the 'Philosophical Transactions' of London. . . . . The people have dug a few feet for coal at the distance of a few yards from the spring. The excavation is too shallow to decide anything except that petroleum rose in the place also as at the spring, thus proving that the bituminous impregnation is not peculiar to that spot. If these remarks should excite any interest in the minds of landed proprietors in that vicinity, I would venture to suggest to them that it would not be wise without some more evidence to proceed to sink shafts, for they would be very expensive and might be fruitless; it would be much wiser to bore, which would enable them, at a comparatively moderate expense, to ascertain the existence, depth, and thickness of the coal, should it exist. But even this should not be done without a previous diligent examination of water-courses, banks, precipices, excavations for wells, cellars, and roads, etc., which might perhaps materially aid the inquiry."

We find in this paper the earliest allusion of which we have any knowledge, to the origin of petroleum as being associated with the coal formations. The allusion, however, is a bare suggestion, and thus a carefully guarded one,

coming from one of the ablest scientists of the day in which he lived, and has given a coloring to many geological speculations as to the origin of petroleum. Its plausibility, seconded by the exalted source from which it emanated, has given it a measure of currency long after more correct geological views have shown its fallacy.

The close and intimate association between deposits of salt in a solid form, or in solution, and petroleum, has long been a matter of observation: indeed, so constant has this been the case, that chemists have sought to utilize the salt in some form of equation, to explain the genesis of the oil. We shall not attempt here to reopen this discussion, and will content ourselves by adverting to this close relationship of oil and salt geologically, to show how this association aided the successful development of the oil business in this country. More than fifty years before petroleum had become an article of commerce, the manufacture of salt from brine, obtained from deep borings, had assumed considerable importance. This business was carried on extensively on the banks of the Kanawha River, in West Virginia. Here it was observed, that in nearly all the wells bored for salt water, more or less petroleum was obtained, sometimes in such quantities as to become a serious annoyance in the successful working of the salt wells. The disagreeable and persistent odor of the oil, contaminated the, then more valuable product, salt. One well was bored for salt in 1814 to the depth of four hundred and seventy-five feet, from which oil was discharged periodically, at intervals of two, three, or four days in

quantities amounting to from thirty to sixty gallons at each eruption. Immense quantities of "natural gas" were also thrown out. Much useful experience, thus gained in boring for salt, was subsequently brought into requisition when the more valuable commodity came into actual use.

As an interesting link in the chain of events leading up to the successful development of oil, we record the business enterprise of a certain Mr. Kier, who, about the year 1849, conceived the thought of putting it up in bottles, and selling it as a specific remedy for all the ills of life. He opened an establishment in Pittsburgh, where it was put on sale in half-pint bottles, which were wrapped in a descriptive sheet with the following label:—

KIER'S

Petroleum or Rock Oil, celebrated for its wonderful curative powers. A natural Remedy. Procured from a well in Allegheny Co., Pa., four hundred feet below the Earth's surface. Put up and sold by Samuel M. Kier, 363 Liberty Street, Pittsburgh, Penna.

Price 50 cents.

Through dint of advertising and the ordinary appliances of the "patent-medicine man," Mr. Kier managed to dispose of about three barrels per day of his "stuff." In the year 1852, however, there was a falling-off in the trade, and the enterprising merchant and *quasi* chemist conceived the idea of improving the quality of the crude oil by distillation, in order to make a fluid suitable for burning in lamps. With a rudely constructed "still" consisting of an iron kettle, to which was adjusted, by clamps and luting, a cover, and an iron worm surrounded by water, he managed

by repeated distillation, to procure a fair illuminating oil of a light wine color. He was unacquainted with the modern method of purification by chemicals, hence his distillate had an odor far more offensive than the original crude oil. We have here, however, at least one of the initial experiments which paved the way for far more extensive refining facilities.

As part of the history of the development of the petroleum industry, it is important to note the origin and rapid growth in a distant part of the globe of the manufacture of a class of mineral oils very closely allied to petroleum. These were obtained from the distillation of bituminous coal such as the bog-head and bituminous shale. As early as 1840 "coal oil" properly so called was produced by the distillation of bituminous shale in France. Between the years of 1840 and 1850 thousands of experiments were made, and immense sums of money expended, chiefly in England and Scotland, in perfecting the machinery employed in its manufacture. At the end of this decade this industry assumed an importance which attracted the attention, both of scientists and capitalists, of other countries. The enormous coal belt, and deposits of bituminous shale in the country, appeared to offer a field of exploration especially inviting to both of these classes. The search was successful, and large veins of suitable material were discovered, and before another decade had completed its course some fifty or sixty "coal oil refineries" had been erected and were in successful operation, yielding manufactured products in every way equal to the foreign articles.

The most important of these were the celebrated "Downer Kerosene Works," located at Boston, Mass.

The term "Kerosene" was a trade mark. "Kerosene oil" was sold throughout the country, and the term is still employed by many to designate any variety of mineral illuminating oil. We may now notice the close connection between these two important industries, and how the successful introduction of the oil manufactured from coal schists paved the way for the more important and vastly more extensive petroleum interests.

The next most important link in this connection is supplied by Mr. George H. Bissel, a gentleman of education and business qualifications. It is stated that he noticed on one occasion, in the year 1853, a bottle of petroleum at the office of Professor Crosby, of Dartmouth College. This had been sent to him as a curiosity by Dr. Brewer, of Titusville, Pennsylvania. It was obtained on his own farm, on Oil Creek, a locality which subsequently became noted, as we shall presently discover. Mr. Bissel, with a sagacity born of inspiration, saw its value, proposed to his partner, Mr. J. E. Eveleth, to proceed at once to Titusville, and prospect the territory. This visit resulted in the purchase of about one hundred acres of land, and the lease of another tract of about the same size for ninety-nine years, for the sum of five thousand dollars, and on the following year the first "oil company" ever formed in the United States was organized under the title of "The Pennsylvania Rock Oil Co.," with a nominal capital of $500,000. This company at once proceeded to "develop

the territory" in a crude way by digging wells and trenching, in order to secure the surface oil. No one at that time associated with them had any acquaintance with the method of boring artesian wells for procuring salt water. The small yield of oil obtained was inadequate to pay expenses, and, as for dividends on stock, such a thing was out of the question. In the course of a year or so samples of the crude oil were sent to Professor B. Silliman, Jr., of New Haven, Connecticut, with instructions to make an exhaustive analysis of the oil. This distinguished chemist made an exceedingly interesting and valuable report to the company. Its length forbids its incorporation here. It describes the general character of petroleum, it furnishes the memoranda respecting the fractional distillation of the oil, which, for accuracy, cannot be excelled even at this date; it gives the densities of the different products and also their boiling poinis. As an evidence of the accuracy of his observations, he states: "The uncertainty of the boiling points indicates that the products obtained at the temperatures named above were still mixtures of others, and the question forces itself upon us, whether these several oils are to be regarded as educts (*i. e.*, bodies previously existing and simply separated in the process of distillation), or whether they are not rather produced by the heat and chemical change in the process of distillation." He accurately describes the proportion of the distilled oils, their behavior under the action of a large number ot chemical reagents, and also their solvent properties upon a number of substances which he enumerates. He also

experimented upon the crude oil as a material for the manufacture of gas. Various modes of distillation were tried; naked heat, steam both in the ordinary way and superheated.

A large number of photometric experiments were made, also of a highly satisfactory character, and, finally, the heavy residuum left in the still was employed as a lubricator for machinery. His conclusion is "that there is much ground for encouragement in the belief that the company have in their possession a raw material from which by simple and not expensive processes they may manufacture very valuable products."

This highly satisfactory report from such a distinguished source enabled the company to secure sufficient capital to proceed. Up to this time, however, singular to relate, it had not occurred to any one associated with the company to obtain the oil by deep boring. We shall now see how important a place in the chain of events may be given to Mr. Kier's "patent medicine," to which we have already alluded. The event, trivial as it may appear, was a key to unlock the difficulty, and set in motion a train of events which is fraught with real interest and importance. I am indebted to Mr. J. T. Henry for a very circumstantial narration of the details of the case. I can only allude to them. He states: "A new day was dawning; a day which witnessed the birth of an idea that gave a new direction to human thought and developed an industry which will forever mark an era in the progress of the world. It was the idea of obtaining petroleum by means

of artesian wells. It was a simple thought, but significant; a thought which, as Professor Silliman remarked, was the one of all others most naturally suggested by the various phenomena that had attended the discoveries of petroleum in the salines of the Muskingum and Kanawha described in a former chapter of this work—the first idea that should have been suggested to a mind cognizant of all these circumstances, and yet, though himself editor-in-chief of the periodical in which the circumstances were described, he very candidly confessed that throughout the five months he was prosecuting the analysis the thought of artesian boring never once occurred to him. And yet, of all in any way connected with these first transactions he was the only one of whom we had a perfectly reasonable right to expect such an idea. But Professor Silliman's interest in the matter terminated with the conclusion of his elaborate analysis, for, though he perfectly comprehended its value, he never expected to see it obtained in any great quantity, and the two hundred shares of stock he held were given him in order to make him president of the company, and thus secure the prestige of a name renowned in science.

"The idea came from another quarter, and was suggested by an incident as trifling as that which disclosed the law of gravitation. While seeking shelter beneath the awning of a Broadway drug store one scorching day in the summer of 1856, Mr. Bissel's eye fell upon a remarkable show-bill lying beside a bottle of 'Kier's Petroleum,' in the window. His attention was arrested by the singularity

of displaying a four hundred dollar bank note in such a place; but a closer look disclosed to him the fact that it was only an advertisement of a substance in which he was deeply interested. He stepped in, and requested permission to examine it. The druggist took it from the window, and, having plenty of them, told him to keep it. For a moment he scanned it, scrutinizing the derricks, and remarking the depth from which the oil was drawn, when instantly, like an inspiration, it flashed upon him that this was the way their lands must be developed by artesian wells."

Although a large amount of interesting material relating to the difficulties and obstacles which impeded every step of the directors in the formation and successful organization of the first oil company formed in this country is at our disposal, we hasten to chronicle only the more salient points of the narrative. Notwithstanding this most pregnant suggestion, which appeared to contain the key to the solution of all their difficulties, nearly two years elapsed before arrangements were completed by the company to send out a man, named E. L. Drake (afterwards dubbed Col. Drake), who was to have charge of the drilling operations. When he arrived on the ground, want of ready money, the novelty of the scheme, the difficulty of finding suitable mechanics, made so many aggravating delays, that it was not until about the middle of June that "Uncle Billy Smith" and his two sons (whom Mr. Kier, the "patent medicine man," had recommended to Mr. Drake), arrived in Titusville. Mr. Henry furnishes the following

interesting details of the boring of the first oil well in America: "Aggravating delays followed. In artesian boring it is necessary to begin on the rock to drill. This had been previously done by digging a common well-hole and cribbing it up with timber. When the rock is within a few feet of the surface it is still the cheapest and easiest method, but in some localities to do so would be practically impossible. They started to dig a hole, but it so persistently caved in and filled with water when they got a few feet below the surface, that Drake determined to give it up and try an experiment that had suggested itself to his mind. This was the driving an iron tube through the quick-sands and clay to the rock. If this is exclusively his own invention, which is probable, it is a pity he did not procure a patent on it. The royalty would have afforded him at least a competency, though the driving pipe is not so much in use as formerly.

"The operators in the oil region have had the benefit of his invention without any return, unless indeed we except the good feeling which prompted them to send him a present of $4200, when they heard he was sick and in need.

"The pipe was successfully driven to the rock thirty-six feet, and about the middle of August the drill was started. The drillers averaged about three feet a day, making slight 'indications' all the way down.

"Saturday afternoon, August 28th, 1859, as Mr. Smith and his boys were about to quit for the day, the drill dropped into one of those crevices, common alike in oil and

salt borings, a distance of about six inches, making the total depth of the whole well 69½ feet. They withdrew the tools, and all went home till Monday morning. On Sunday afternoon, however, 'Uncle Billy' went down to the well to reconnoitre, and peering in he could see a fluid within eight or ten feet of the surface. He plugged one end of a bit of tin rain-water spout and let it down with a string. He drew it up filled with petroleum.

"That night the news reached the village, and Drake, when he came down next morning bright and early, found the old man and his boys proudly guarding the spot, with several barrels of petroleum standing about. The pump was at once adjusted, and the well commenced producing at the rate of about twenty-five barrels a day. The news spread like lightning. The village was wild with excitement. The country people round about came pouring down to see the wonderful well. Mr. Watson jumped on a horse and hurried straightway to secure a lease of the spring on the McClintock farm near the mouth of the creek. Mr. Bissel, who had made arrangements to be informed of the result by telegraph, bought up all the Pennsylvania rock-oil stock it was possible to get hold of, soon securing most of that owned in New Haven, and four days afterwards was at the well."

This memorable strike ushered in the PETROLEUM ERA. The identity or similarity between the distilled products of coal and petroleum had already been established by the experiments of Professor Silliman. The great usefulness as an illuminator, and the commercial value of the former

product, were also settled factors in the calculation. It now only remained to develop this "bonanza."

As was to be expected the excitement throughout that section was intense, and the "oil fever" fairly set in. It has not yet run its course. Millions of money since that day have been expended in procuring the oil, and thousands have been enriched by these ventures; while, on the other hand, the greater number venturing on the sea of wild speculation have been hopelessly bankrupted. Every spot of ground, with or without "surface indications," within the oil belt before indicated, became in its turn the centre of a busy population, every one diligently engaged in some branch of industry directly connected with the all-absorbing thought of oil mining. Towns would spring up as if by magic. Large hotels were built to accommodate the rush of speculators in oil and oil lands. Capitalists, seeking investments, merchants and builders in great numbers thronged this new El Dorado. Wells were drilled in every spot which promised success. In a certain locality large paying wells would be opened. The oily treasure gushed forth from the rock in abundance. A town, a city immediately sprang up in the wilderness. Then a change would suddenly come over the scene, and, like a dissolving panorama, it would vanish from view. In a few months, or at most a year or two, the territory which had been held at fabulous prices became unsalable, and the period of decadence would set in, while fresh fields of discovery were sought for. The sudden emergence of a city from a complete wilderness, its temporary marvellous

development and prosperity, followed by its rapid decadence and complete abandonment, are perhaps nowhere better illustrated than in the history of Pithole City. In May, 1865, there were ten houses on the ground. A short time before, the "United States Well" was completed and commenced to flow, as was estimated, at the rate of 650 barrels per day. The excitement spread throughout the oil region. In August of the same year the population had grown to 14,000, and the daily yield of that section was 5000 barrels of oil. At one time there were fifty hotels to accommodate the rush of strangers, speculators, and adventurers of all kinds; three of these were palatial in size and accommodations. Its streets were lined with imposing structures, including banks, school-houses, churches, and places of amusement. Soon after the yield of oil began to decrease; signs of decadence began to be visible in the diminished tread of busy men in its streets. The collapse soon became final. The population moved away; the buildings were deserted; the miners sought more promising fields, and in about one year afterwards a destructive fire saved from a decay and destruction equally sure, but less rapid, about all what was left of the town. The history of Pithole City, with but little variation, is that of a score or more of other places within the oil region. At or about this time a visit to this wild section of Western Pennsylvania was full of interest, and to any one who could cheerfully put up with the rude accommodations the places offered, and with the still ruder manners of the wild adventurers who thronged there from

every point of the compass, the trip was one replete with a kind of romantic enjoyment, novel and strange. For miles around in every direction the tourist was never out of sight of the derrick, the puffing engine, the huge piles of barrels, and the enormous iron tanks filled with oil. Temporary tramways were stretched in every direction to facilitate the movement of the oil. Immense teams of horses or mules were employed in the transportation of the oil from the wells, either to the nearest railroad station or to the flat-boats on Oil Creek. The surface of the whole country was saturated with oil from the leakage of barrels, the overflow and enormous wastage from the wells before they could be got under control, and from the leakage and bursting of tanks. The peculiar odor of petroleum pervaded everything; the air for miles was thoroughly saturated with it; nothing else was thought of; nothing else was talked about. Land was sold at thousands of dollars per acre. Fortunes were, literally and without exaggeration, made and lost in a day. Oil companies with high-sounding names were organized almost without number, absorbing millions of money; many companies were formed without the shadow of a basis for operations, and hundreds who were as covetous as they were ignorant were drawn in the mælstrom of speculative excitement and hopelessly ruined. No parallel in the history of speculations in this country can be found, excepting, perhaps, that which occurred during the "California gold fever" of 1849.

It would extend this chapter entirely beyond our prescribed limits were we to attempt to follow and to describe

the successive developments of the various oil centres as they in turn rose in prominence, on account of the striking of some "great gusher," and then yielded to the decadence which uniformly followed the decrease in the oil output. It will be sufficient to summarize by stating that the oil men, commencing at Titusville, having fairly honeycombed, with the industrious drill, both sides of Oil Creek almost to the summits of the mountains fringing its course, down to its mouth, where it empties its slimy waters into the Allegheny River, next turned their attention to the valley of this stream which was also actively prospected with variable success. "Farms" were leased or bought; royalties of one-half, one-fourth, or one-eighth of the oil produced often formed part of the agreement entered into. The first "fountain well," or as it was afterwards universally called, "flowing well," was struck on what was then known as the upper "McElhenny or Funk" farm, and commenced to flow at the rate of three hundred barrels per day. At that time such a thing had never been heard of. It was supposed by some that now the great oil basin had been surely tapped, and at the rate the well was pouring forth its liquid treasure it must soon exhaust itself and bring ruin upon all the neighboring wells; but it continued to flow on with little variation for fifteen months, and during this time it remained a source of vast profit to its owners and a marvel to beholders.

Shortly after this successful strike, a second flowing well, this time on the Tarr Farm, known as the Phillips Well, burst forth with a stream of three thousand barrels a day,

and very soon a third, on the Funk farm, in close proximity to the first, when completed, astonished and delighed its owners with a yield equal to the last mentioned, viz., three thousand barrels per day. Among the most productive "farms" on the creek, may be mentioned the Farrel "farm," upon which was located the "Noble and Delamater" Well, which flowed three thousand barrels of oil per day. It commenced to flow in 1863 and continued to flow till 1865, and is estimated to have produced upwards of three million dollars' worth of oil. On the opposite side of the creek the celebrated Sherman Well was struck, which began flowing in 1862 at the rate of two thousand barrels. It has been stated that this well for two years flowed at the average rate of nine hundred barrels per day. After it ceased to flow it was successfully pumped.

On what has been called the lower McElhenny farm was located another celebrated flowing well, the "Empire," which commenced to flow at the rate of two thousand five hundred barrels.

We deem it unnecessary further to particularize the development of the "farms" as they successively came into prominence. The speculative history of one repeats itself continually. The number of wells already put down, most of which were in successful operation, numbered thousands. The daily output of oil continued to increase; new territories continued to be prospected. Venango County proved too small a field for the thousand greedy adventurers who thronged this section. It so happened that the general trend of the two streams, Oil Creek and

Allegheny River, were in the direction of the plateau of the oil-bearing sands, and it became a difficult matter to divest the seekers after oil of the idea, that oil was only to be found on the banks of some stream. Hence most of the search for a long time was confined to the banks of rivers and creeks. More correct geological knowledge has served to impart sounder views and corrected the impression that the mere bed of a stream of water could possibly indicate the nature of the strata, lying perhaps thousands of feet below.

Clarion and Butler counties, both adjoining Venango, together with Armstrong County, forming what has been called the Southern Field, contained rich deposits of petroleum and have been successfully developed. One of the largest continuous deposits of oil sand yet discovered stretches through part of both of the first named of these two counties, and throws off a spur into Armstrong, in the general direction before indicated. Northeast and southwest, to the north and east of Venango County, lies Warren County, with some exceedingly productive wells. East of this again we have the enormously productive district of Bradford, in McKean County, from which, at present, the largest part of the petroleum produced is received. The Bradford district crosses the State line and enters New York State, in Cattaraugus County. This district together with the Allegany district in Allegany, New York, forms the Northern oil field. The Middle oil field lies chiefly in Warren County. These oil fields are divided into districts with distinctive names, and are not only miles apart from each other, but are characterized by entirely distinct oil-

bearing sand, evidently evincing a distinct geological formation, having no connection with each other, and probably deposited at widely different geological periods. Mr. Chas. A. Ashburner, Geologist in charge Pennsylvania Survey, furnishes the following list of oil-producing areas with a brief description of the sand characterizing each. This schedule comprises those producing areas which were yielding oil during the year 1884. The names of many famous oil centres now exhausted and abandoned will be missed from this list.

Northern Oil Field.

"*Black Sand.*"

Oil sand, fine-grained, friable, very seldom containing pebbles as large as pin-heads. Color black, dark brown, or chocolate-brown; hence compared to coffee grounds, chocolate, or ashes from red-ash coal.

Oil: dark amber, green, occasionally black. Gravity heavier than oil from Venango 3d sand. The average daily yield from the Allegany district of this field during the year 1884, was 7000 barrels.

No. 1. Richburg or Allegany field.
" 2. Niles. A few small wells; dark oil.
" 3. Wirt. " " " much gas; some oil.
" 4. Waugh and Porter. Small wells. Amber oil.
" 5. Harding-O'Connor. Small wells.

Bradford District.

No. 6. The great Bradford field.
" 7. Limestone, sands, and oils, variable.
" 8. Kinzua. Large and long-lived wells.
" 9. Windfall Run. Small wells, recent development.

The average daily production of this district during the year 1884 was 28,000 barrels.

Middle Oil Field.

" White and Gray Sands."

Oil sands irregular in their geological relations, as well as in composition and color; generally grayish and fine-grained, but sometimes white, coarse-grained and pebbly in streaks; oils, amber, ranging from dark amber, to light amber, with considerable variation in gravity.

No. 10.	Sugar Run.	Small wells.
" 11.	Dew Drop.	Fair wells.
" 12.	Warren and N. Warren.	Irregular sands, productive in spots.
" 13.	Glade Run.	Irregular sands, productive in spots.
" 14.	Wardwell.	" " " " "
" 15.	Clarendon.	Fair wells and long-lived.
" 16.	Garfield or Cherry Grove.	Large wells.
" 17.	Balltown.	Large wells.
" 18.	Cooper and Sheffield.	Spotted.

The average daily production of this field during June, 1884, was 12,000 barrels, with a large decline for December to 6000 barrels.

Southern Oil Field.

Venango Oil Sand Group.

White, grayish-white, and yellowish sandstones, generally friable and coarse grained, and frequently true conglomerates with water-worn quartz pebbles as large as hazelnuts.

Oils, green, black, and in some cases, amber. Gravity ranging from 30° to 51° B. Third sand oil 48° B.

No. 19. Tidioute, Triumph, New London, and Colorado.
" 20. Atlas or Grand Valley.
" 21. Brenn Farm. A few small wells.
" 22. Church Run.
" 23. Octave.
" 24. Sodorus Farm. A few small wells.
" 25. Enterprise.
" 26. Landers's Farm. A few small wells; amber oil.
" 27. Fagundus.
" 28. Dunn's Run. A few small wells; black oil.
" 29. Neill Farm. A few small wells.
" 30. Stufflebeam Farm. Small wells.
" 31. Allender Farm. Small wells.
" 32. McGroary Farm. Small wells.
" 33. White Farm. Small wells; heavy oil.
" 34. Green Farm or West Hickory. Principally heavy oil.
" 35. Sowers and Jamieson Farms. Principally heavy oil.
" 36. Hunter Run, Tionesta. A little heavy oil.
" 37. Oil Creek, Shamburg, Pleasantville.
" 38. Pithole.
" 39. Cashup.
" 40. Walnut Bend.
" 41. Henry's Bend.
" 42. Sugar Creek, Cooperstown. Heavy oil in small quantities.
" 43. Sugar Creek. McCalmont Farm. Heavy oil in small quantities.
" 44. Sugar Creek and French Creek. Heavy oil in small quantities.
" 45. Utica. A little heavy oil.
" 46. Franklin and vicinity. Lubricating oil from first sand.
" 47. Two Mile Run. Second sand oil.
" 48. Reno Oil Belt. Large wells.

No. 49. Sage Run. Good wells.
" 50. Hoge Farm. A few small wells.
" 51. Norway. A few small wells.
" 52. Raymilton. Moderate wells.
" 53. Lower Two Mile Run and Cochran Farm.
" 54. Foster's. Good wells. Second and third sands.
" 55. Cranberry. Good wells. Second and third sands.
" 56. Gas City. Much gas and considerable oil.
" 57. Scrubgrass. Large wells.
" 58. Bullion. Large wells.
" 59. Six Corners. Fair wells.
" 60. Emlenton. Small wells.
" 61. Clarion, Butler, and Armstrong.
" 62. Butler Cross Belt. Large wells in fourth sand.
" 63. Rumbaugh Farm. Two or three small wells.
" 64. Whiskey Run. Good wells.
" 65. Brady's Bend. Small wells.
" 66. Kalor. Good wells.
" 67. Somerville Farm. "Refined oil," almost white; gravity 51° B.
" 68. Baldridge. Some large wells; spotted; recent development.
" 69. Freedom. Two or three gas wells with a little oil.

The average daily production of oil in the Southern oil field for the month of June, 1884, was 8000 barrels, with a large increase for December, amounting to 17,000 barrels.

MISCELLANEOUS.

Oil from Sandstone above Venango Group.

No. 70. Slippery Rock. Heavy oil from base of Coal Measures. Amber from Berea grit.
" 71. Smith's Ferry. Heavy oil from base of Coal Measures. Amber from Berea grit.

No. 72. Pleasant Unity. Oil from Mahoning sandstone.
" 73. Dunlap Creek. Small quantities of oil from Mahoning sandstone (?).
" 74. Whitley Creek. Mahoning sandstone (?) and measures above.
" 75. Dunkard Creek. Mahoning sandstone (?) and measures above.

We have thus enumerated seventy-five distinct oil pools now producing oil, within what has been termed "the great American oil field" lying chiefly in Pennsylvania, but stretching across into New York. Many of these are small in extent, comprising a few hundred acres of land: others are miles in extent, as for example, the Clarion, Butler, and Armstrong district, which is about thirty miles in length and stretches into the three counties from which it takes its name. It is, however, only four or five miles in width. These oil spots are very irregular in shape, so far as they have yet been defined by the outlying "Wild-Cat" wells.

Oil Production.

The yield of oil during the years 1860, 1861, and 1862, although small compared with that subsequently produced, was far in advance of the actual demand. From the 'Derrick's Handbook of Petroleum,' Notes for 1860, we have a memorandum for the month of October (just after the great outflow of the Phillips wells on the Tarr farm, whose first-day yield was 4000 barrels, with the Empire flowing at the rate of 2500 barrels). "So much oil is produced *it is impossible to care for it*, and thousands of barrels are running to waste into the creek. The surface of the river

is covered with oil for miles below Franklin. Fears are entertained that the supply will be soon exhausted, if something is not done to prevent the waste." In 1862, oil sold for ten cents per barrel. The export demand had scarcely begun. The home trade for want of suitable lamps was yet in its infancy. For the present the production was far in excess of the demand.

From a great variety of causes, more interesting to the producer than to the general reader, it has been difficult to estimate with entire accuracy the annual yield of petroleum. The early mode of transportation in bulk, boats, and barrels, tended greatly to the confusion of any estimate that might be given. Such a variety of causes were at work also, either to depress the price or to raise it, that all estimates had to be received with caution. The present more perfect system of handling oil has changed this aspect of the subject, and the figures which we present in this connection have been adopted from the Statistical Chart of the Second Geological Survey of Pennsylvania (1886).

Table showing the Yearly and the Total Production of the several Oil Districts of Pennsylvania and New York, from the commencement of developments to January 1, 1883.

YEAR.	Oil Creek Division.	Central Allegheny Division.	Tidioute and Fagundus Division.	Beaver and Smith's Ferry Div.	Pithole and Cashup Division.	Butler and Armstrong Division.	Clarion Division.	Bradford Division.	Warren and Forest Division.	Bullion Division.	Allegany County Division, New York.	TOTAL BARRELS OF 42 GALS.
1859	2,000	......	......	......	......	......	......	......	......	......	......	2,000
1860	120,000	75,000	5,000	......	......	......	......	......	......	......	......	200,000
1861	1,870,000	170,000	50,000	20,000	......	......	......	......	......	......	......	2,110,000
1862	2,860,000	125,000	40,000	30,000	......	......	......	......	......	......	......	3,055,000
1863	2,480,000	80,000	30,000	20,000	......	......	......	......	......	......	......	2,610,000
1864	2,000,000	85,000	30,000	15,000	......	......	......	......	......	......	......	2,130,000
1865	1,600,000	100,000	100,000	20,000	900,000	1,000	......	......	......	......	......	2,721,000
1866	2,000,000	200,000	600,000	25,000	900,000	5,000	2,000	......	......	......	......	3,732,000
1867	1,950,000	200,000	850,000	20,000	550,000	8,000	5,000	......	......	......	......	3,583,000
1868	2,300,000	300,000	750,000	20,000	300,000	25,000	20,000	1,000	......	......	......	3,716,000
1869	3,000,000	350,000	800,000	20,000	100,000	45,000	35,000	1,000	......	......	......	4,351,000
1870	2,900,000	400,000	1,000,000	20,000	75,000	900,000	75,000	1,000	......	......	......	5,371,000
1871	2,200,000	800,000	1,000,000	20,000	100,000	1,100,000	310,000	1,000	......	......	......	5,531,000
1872	1,700,000	800,000	1,100,000	25,000	200,000	1,700,000	830,000	2,000	......	......	......	6,357,000
1873	1,200,000	800,000	900,000	30,000	100,000	4,400,000	2,500,000	2,000	......	......	......	9,932,000
1874	800,000	500,000	400,000	30,000	50,000	5,200,000	3,900,000	3,000	......	......	......	10,883,000
1875	550,009	400,000	350,000	35,000	40,000	4,650,000	2,750,000	25,000	1,000	......	......	8,801,000
1876	650,000	350,000	350,000	35,000	30,000	4,700,000	2,400,000	380,000	55,000	65,000	......	9,015,000
1877	800,000	450,000	310,000	62,000	15,000	5,500,000	3,000,000	1,450,000	150,000	1,306,000	......	13,043,000
1878	750,000	350,000	300,000	92,000	10,000	4,500,000	2,250,000	6,500,000	110,000	505,000	......	15,867,000
1879	500,000	250,000	250,000	82,000	5,000	2,800,000	1,400,000	14,200,000	50,000	290,000	......	19,827,000
1880	400,000	170,000	230,000	103,000	3,000	1,700,000	900,000	22,300,000	90,000	147,000	5,000	26,048,000
1881	350,000	150,000	220,000	100,000	......	1,400,000	850,000	23,000,000	440,000	128,000	600,000	27,238,000
1882	280,000	155,000	195,000	80,000	......	1,300,000	600,000	18,000,000	3,300,000	100,000	6,450,000	30,460,000
Total	33,262,000	7,260,000	9,860,000	904,000	3,378,000	39,934,000	21,827,000	85,866,000	4,196,000	2,541,000	7,055,000	216,083,000

The foregoing table has been compiled from various sources, and is believed to be as reliable as any published. Absolute accuracy cannot be claimed, for the figures of yearly production have always been little better than estimates; the inconstancy of oil wells, the fluctuations in the tide of developments, and the careless habits of the average oil producer, make the systematic collection of reliable statistics impossible. The yearly output from the whole oil region may be closely calculated, but the detailed production of districts can only be estimated approximately. As there is confessedly so much uncertainty in the primary data, it would be pretentious to employ other than round numbers in the totals. In the table no account is taken of any quantity below 1000 barrels; consequently some of the districts or divisions are not included in this table until several years after they commenced to produce oil.

In order to make the table of the production as complete as possible, we add also from the Second Geological Survey the following figures:—

Total production to 1882 inclusive	216,083,000
1883	24,300,000
1884	23,500,000
1885	20,900,000
Total production in barrels of 42 gallons each	284,783,000

The production of oil appears to have reached its maximum in 1882, in which year the largest *daily* average yield was 110,000 barrels.

Frequent allusion has been made in the geological section of this work to the first, second, and third "sands." To illustrate the relative productiveness of the different strata, the following table representing the production of oil for 1880 has been prepared:—

	Barrels, 42 gals.
Northwestern Pennsylvania	23,915,446
West Virginia and Washington County, Ohio	219,254
Beaver County, Pennsylvania	86,803
Glasgow, Kentucky	5,376
Grafton, Ohio	4,159
Greene County, Pennsylvania	3,118
Mecca, Ohio	900
Erie, Pennsylvania	25
	24,235,081

	Barrels, 42 gals.
First sand oil	101,704
Second sand oil	176,766
Third sand oil	23,869,808
Beaver County, Pennsylvania	86,803
	24,235,081

The great bulk of this petroleum, it will be noticed, came from the third sand rock, at an average depth from the surface of about 1650 feet. The Bradford oil territory comprising a portion of the Northern Field began to be developed in 1875. Its yield continued to increase year by year until its maximum enormous output of 25,846,271 barrels was reached in 1881. Since then its production has declined, and in 1884, was only 12,096,950 barrels.

It was within the boundaries of Butler County, Penna.,

that, in the month of October, 1884, the largest flowing well ever opened in this country, gushed forth its treasured wealth and at the rate of nine or ten thousand barrels per day. This rate of flow continued, however, only for a short time. In a few days it perceptibly diminished, and in less than two months it dropped to about five hundred barrels. The following interesting particulars respecting this celebrated well have been furnished to the author by Mr. F. H. Taylor, Oil City, Penna., the editor of the 'Derrick's Handbook of Petroleum,' in a letter bearing date January 29, 1885. "This well was drilled through the sand October 25 and 26, 1884, and being filled with salt water, it made no show of oil. It was 'shot' October 27. The owners were not expecting a large well, and consequently were not prepared for it. The result of the torpedo was, that the well began flowing at a rate estimated from four hundred to five hundred barrels an hour. All this oil flowed on the ground for six hours, so that it is impossible to more than estimate its production for that time; but I think it safe to say, that in some one hour of that time it made 500 barrels, or, at that rate, of 12,000 barrels a day. About dark they got part of the oil turned into a tank and with a gauge, and an estimate of what was being lost, made its production at that time 430 barrels an hour. We generally call its first day's production 7500 barrels, because that was all that was saved from it; but its actual output was undoubtedly 9000 to 10,000 barrels, and may have been more."

The following table from the 'Petroleum Age' of July, 1886, published at Bradford, Pa., shows the average daily runs, by districts, in the petroleum regions for 1882–86. (In barrels of 42 gallons each):—

	Bradford.	Allegany.	Cherry Grove.	Cooper.	Balltown.	Wardwell.	Baldridge.	Cogley.	Macksburg.	Kane.	Washington.	All other fields.	Total.
1882.													
January	55,006	7,222	...	...	...	...	...	...	...	...	...	11,541	73,769
February	63,313	9,512	...	...	...	...	...	...	...	...	...	10,722	83,547
March	58,078	14,760	...	...	...	...	...	...	...	...	...	10,894	83,732
April	53,108	17,622	...	...	...	...	...	...	...	...	...	10,395	81,125
May	55,955	19,522	218	...	...	...	...	...	...	...	...	11,262	86,957
June	56,016	22,765	3,037	...	...	...	...	...	...	...	...	13,968	95,786
July	52,456	23,884	8,655	...	...	...	...	...	...	...	...	19,311	104,306
August	49,711	20,814	24,315	...	...	...	...	...	...	...	...	10,985	105,825
September	46,585	16,387	23,002	...	...	...	...	...	...	...	...	10,567	96,541
October	42,107	19,964	9,363	120	...	...	...	...	...	...	...	14,286	85,840
November	41,404	16,993	4,886	294	...	...	...	...	...	...	...	10,012	74,589
December	39,580	14,020	3,180	558	87	...	...	...	...	...	...	14,993	72,419
1883.													
January	36,487	14,106	3,313	1,632	334	...	...	...	...	...	...	8,893	65,125
February	38,481	13,154	2,954	1,475	332	...	...	...	...	...	...	8,812	65,208
March	37,754	12,619	2,706	1,737	368	...	..	...	...	...	...	9,220	64,404
April	38.810	13,742	2,604	3,802	840	...	...	...	...	...	...	9,409	69,207
May	39,039	13,793	2,207	3,829	952	...	...	...	...	...	...	9,625	69,445
June	38,614	13,499	2,215	4,199	1,961	...	...	...	...	...	...	9,955	70,443
July	36,489	12,381	1,891	3,467	1,944	...	...	...	...	...	...	9,456	65,628
August	37,165	12,743	1,935	3,166	3,078	...	...	...	...	...	...	10,790	68,877
September	35,894	12,358	1,612	3,200	3,723	...	...	...	...	...	...	9,423	66,210
October	35,654	12,757	1,312	3,314	4,298	...	...	...	...	...	...	10.314	67,649
November	34,516	12,332	1,000	3,251	3,807	...	...	...	...	...	...	10,285	65,281
December	32,650	11,752	1,061	2,876	3,766	...	...	...	...	...	...	10,725	62,830
1884.													
January	31,020	11,018	767	2,908	2,808	...	...	...	86	...	...	9,657	58,264
February	33,987	12,025	968	3,743	2,816	...	...	...	51	...	...	11,034	64,624
March	33,049	11,777	1,001	4,631	2,813	...	...	...	86	...	...	11,319	64,676
April	34,370	12,261	1,039	4,229	2,399	475	844	...	113	...	...	10,176	65,906
May	34,946	12,193	968	3,468	2,260	1,015	1,061	...	136	...	...	10,777	66,824
June	35,701	11,672	845	2,985	2,250	2,042	969	...	211	...	...	10,886	67,561
July	34,718	11,114	523	2,476	2,471	4,277	889	...	249	...	...	10,234	66,951
August	33,782	10,384	665	2,046	2,189	6,483	843	...	258	...	...	10,601	67,254
September	33,449	9,989	653	2,155	2,115	4,056	2,644	...	334	...	...	10,891	66,286
October	31,500	8,802	446	1,811	1,781	2,201	6,034	...	350	...	...	10,489	63,414
November	29,552	8,642	423	1,302	1,401	1,346	9,493	...	431	...	...	9,592	62,182
December	30,632	8,193	407	1,246	1,189	979	8,730	...	315	...	...	10,367	62,058
1885.													
January	27,254	7,442	360	1,214	810	977	6,199	...	384	...	...	9,034	53,674
February	27,480	7,696	327	987	910	663	7,349	...	637	...	...	9,564	55,613
March	26,833	7,342	373	867	954	605	7,239	...	873	...	...	9,885	54,971
April	29,557	7,738	299	1,114	775	527	9,333	...	1,189	...	...	11,019	61,551
May	28,443	7,467	343	1,053	902	722	7,488	127	1,557	...	...	10,879	58,981
June	30,662	7,680	439	1,000	1,044	764	5,905	609	2,233	...	...	11,983	62,319
July	30,657	7,363	467	906	1,032	647	3,856	1,220	2,441	...	...	10,283	59,872
August	29,291	7,102	363	923	930	...	2,268	2,115	2,382	...	...	12,731	58,105
September	30,151	6,647	312	918	944	...	2,021	3,244	2,270	...	...	13,830	60,337
October	30,828	7,081	428	777	925	...	1,898	4,939	2,053	...	...	14,194	63,123
November	29,117	6,667	303	707	1,030	...	1,469	5,416	2,031	...	...	14,162	60,902
December	30,376	6,738	442	749	1,182	...	1,420	5,241	1,971	96	...	14,054	63,269
1886.													
January	27,966	6,235	306	623	1,063	...	1,288	4,469	1,768	70	...	14,398	58,186
February	27,499	6,361	305	571	1,056	...	1,218	3,969	1,775	435	497	14,552	58,238
March	29,333	6,545	353	653	1,059	...	1,369	3,847	1,897	1,252	900	16,247	63,455
April	28,640	6,895	347	583	832	...	1,299	3,618	2,138	3,017	1,734	17,263	66,366
May	27,552	6,535	338	591	1,376	...	1,218	3,258	1,890	4,475	5,397	17,862	70,492
June	28,790	6,981	344	605	1,104	...	1,339	2,936	2,179	5,702	8,022	19,988	77,990

PRICES OF PETROLEUM.

The price at which petroleum was sold for the first two or three years fluctuated violently. When efforts were being made to "float" the stock of the first oil company (the Drake Well Company) the oil was estimated to be worth 75 cents per gallon. In 1860 the highest price obtained for it was $19.25 per barrel of 42 gallons, or about 45¾ cents per gallon. In 1861 it almost ceased to have any market value, and thousands of barrels were suffered to flow into the streams or upon the surface of the ground. Where storage tanks were available it was stored at the rate of ten cents per barrel. The following table furnishes the yearly average price of crude petroleum, per barrel, at the wells for the years 1860–1884; also the highest and lowest prices for each year.

Year.	Highest.	Lowest.	Average.
1860	$19.25	$2.75	$9.59
1861	1.00	.10	.49
1862	2.25	.10	1.05
1863	3.95	2.25	3.15
1864	12.12½	4.00	8.06
1865	8.25	4.62½	6.59
1866	4.50	2.12½	3.74
1867	3.55	1.75	2.41
1868	5.12½	1.95	3.62½
1869	6.95	4.95	5.63¾
1870	4.52½	3.15	3.84
1871	4.82½	3.82½	4.34
1872	4.02½	3.15	3.64
1873	2.60	1.00	1.83
1874	1.90	.69½	1.17
1875	1.75	1.03	1.35

Year.	Highest.	Lowest.	Average.
1876	3.81	1 80	2.56½
1877	3 53¼	1.80	2.42
1878	1.65¼	.82⅛	1.19
1879	1.18⅛	.67⅛	.85⅞
1880	1.06¼	.78	.94¾
1881	.94½	.76⅞	.85⅞
1882	1.14	.54⅜	.78⅞
1883	1.24¾	.83¾	1.04¼
1884	1.11¼	.63½	1.02¾

The following table from the 'Petroleum Age' for October, 1886, published at Bradford, Pa., shows the average price of crude petroleum certificates on the floor of the Bradford Oil Exchange from March 1, 1879, to August, 1886, inclusive.

Month.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.
January	...	110½	95	83	92¾	111⅛	70¾	88¼
February . . .	...	103¼	89¼	85¼	101	104⅜	73⅝	80
March	86	89	82⅞	80⅞	97⅜	100⅛	80⅜	77⅛
April	78⅜	76⅝	84⅛	78¼	92⅝	94	78⅞	74
May	78½	80¼	81½	70	99⅜	85⅜	79⅝	69⅞
June	68⅞	100¼	81	54⅜	117¼	68¾	82¼	67
July	69⅞	101¼	76⅜	57⅝	108	63½	96⅝	66
August	67¼	90¾	78⅜	58⅜	108⅜	81⅛	100⅝	62
September . . .	69¼	95⅛	92¼	71⅛	112⅛	78	100¾	63⅜
October	88⅝	96¾	92¾	93⅝	111⅛	71	105⅛	...
November . . .	105⅜	91¼	82⅜	114¾	114⅛	72⅝	104⅝	...
December . . .	113¼	92⅜	83¾	95¼	114⅛	74⅜	89⅝	...

With the average price per barrel for each year and the number of barrels produced it is a matter of simple arithmetic to ascertain the actual value of the output for each year, and, finally, the total value of the oil raised. The subjoined table is furnished by the United States Census Bureau, giving statistics up to the year 1880, inclusive. The remainder are obtained from the 'Derrick's Handbook.'

Year.	Number of barrels.	Average price per barrel.	Total value.
1860 . . .	500,000	$9.00	$4,800,000.00
1861 . . .	2,113,609	.49	1,035,668.41
1862 . . .	3,056,690	1.05	3,209,524.50
1863 . . .	2,611,309	3.15	8,225,623.35
1864 . . .	2,116,109	9.87[2]	20,896,576.37
1865 . . .	2,497,700	6.59	16,459,843.00
1866 . . .	3,597,700	3.74	8,066,993.00
1867 . . .	3,347,300	2.41	13,217,174.12
1868 . . .	3,646,117	3.62[2]	23,730,450.00
1869 . . .	4,215,000	5.63	20,503,753.63
1870 . . .	5,260,745	3.89¾	22,591,179.94
1871 . . .	5,205,341	4.34	21,440,502.72
1872 . . .	5,890,248	3.64	18,100,464.12
1873 . . .	9,890,964	1.83	12,647,526.84
1874 . . .	10,809,852	1.17	11,863,133.10
1875 . . .	8,787,506	1.35	11,863,133.10
1876 . . .	8,968,906	2.56¼	22,982,821.62
1877 . . .	13,135,771	2.42	31,788,565.82
1878 . . .	15,163,462	1.19	18,044,519.78
1879 . . .	20,041,581	.85⅞	17,210,707.68
1880 . . .	26,032,421	.94½	24,600,637.84
1881 . . .	29,674,458	.85¼	25,345,877.72
1882 . . .	31,789,190	.78½	24,954,514.15
1883 . . .	24,385,966	1.07¼	26,284,913.45
1884 . . .	23,596,945	1.02¾	24,127,876.26
	266,334,890		$443,991,980.52

Exports of Petroleum and its Products from the United States during the fiscal years, ending June 30, *from* 1864 *to* 1886, *both inclusive, compiled from Official Reports of the Treasury Department.*

Year.	No. of gallons.	Value.
1864	23,210,369	$10,782,689
1865	25,496,849	16,563,413
1866	50,987,341	24,830,887
1867	70,255,481	24,407,642
1868	79,456,888	21,810,676
1869	100,636,684	31,127,433

Year.	No. of gallons.	Value.
1870	113,735,294	32,668,960
1871	149,892,691	36,894,810
1872	145,171,583	34,058,390
1873	187,815,187	42,050,756
1874	247,806,483	41,245,815
1875	221,955,308	30,078,568
1876	243,660,152	32,915,786
1877	309,198,914	61,789,438
1878	338,841,303	46,574,974
1879	378,310,010	40,305,249
1880	423,964,699	36,218,625
1881	397,660,262	40,315,609
1882	559,954,590	51,232,706
1883	505,931,622	44,913,079
1884	513,660,092	47,103,248
1885	574,668,180	50,257,947
1886	577,781,752	50,199,844

The 'Derrick's Handbook of Petroleum' places the amount of stock held by the pipe lines on December 31, 1884, at 36,872,892 barrels. We have no accurate means of estimating the amount held in the private tanks of refiners and others.

We have thus, in the briefest manner possible, endeavored to place before our readers the history of the origin and growth of the petroleum industry in this country. From the large amount of statistics and other material which it has been necessary to examine, we have selected only the more salient points which would be of interest to the general reader. We have watched its growth from the sale of a few barrels to as many millions. How much it has promoted the happiness and comfort of the multitudes upon whom it has shed its mild and beautiful light cannot be estimated or written.

CHAPTER VI.

THE CHEMISTRY OF PETROLEUM.

As might easily be conjectured, from the great variety of forms it assumes, petroleum varies in its chemical composition. It is essentially a hydro-carbon of a highly complex character, and, although other chemical elements are frequently associated with it, they may be regarded as accidental, rather than essential, components. It is now considered by the best chemists to belong to the hydro-carbon compounds of the paraffine series. The name "paraffine" was given to this class of compounds on account of their strange resistance to the action of almost every chemical reagent. Hence the derivation from *parum* and *affinis*. This series of compounds is generally described under the algebraical symbol C_nH_{2n+2}, which, being interpreted, means that having the number of atoms, say of carbon, furnished, we have the complete formula deduced from the above equation by simply doubling this for the hydrogen and adding thereto the number two. We have, for instance, as one of the series, a compound containing four atoms of carbon, we apply the above formula and have—

$$C_4H_{(4\times2+2=10)} \text{ or } C_4H_{10}.$$

Petroleum has been frequently subjected to analysis. The constituents alluded to above which may be described

as accidental are: (1) nitrogen, (2) oxygen, (3) sulphur, and it has been stated that gold in small quantities has been found in the ashes of crude petroleum and in the residuum of petroleum stills. In one case thirty-four dollars' worth of gold was obtained by Mr. John Turnbridge from a ton of residuum, the source of which is not given. Sulphur exists in small and varying proportions in almost every variety. It is frequently noticed in the exit pipe conveying the gas from the stills in refineries, in such quantities as sometimes to effectually close the pipe. Some varieties of petroleum are heavily charged with it. Petroleum from Canada and California contains a much larger proportion of sulphur than the oil from Western Pennsylvania.

The presence of sulphur beyond a small percentage is a serious disadvantage to the oil, and adds greatly to the expense of refining. Metallic arsenic also, it is said, has been noticed to condense in the goosenecks of the retorts in which the bituminous limestones of Lobsan are distilled.

The chemist Reichenbach, in the year 1824, published his analysis of paraffine and some ten years later made experiments in the analysis of petroleum. He made the discovery that these oils consisted of a number of distinct compounds having varying specific gravities and boiling-points. These results were partially verified by Laurent. It was afterwards discovered that many of the products obtained by them were mixtures also of heavy and light oils capable of still further division. Some highly interesting experiments were made in the same direction, viz., that of isolating the different compounds, in the year 1863, by

Schorlemmer in England and Pelouze and Cahours in France. The examination was made upon American petroleum. The results obtained by Schorlemmer indicated the presence of the same hydro-carbons which are obtained by the distillation of cannel coal, while Pelouze and Cahours showed that the distillates were all homologues of methane, or marsh gas, and belonged to the series of hydro-carbons represented by the formula $C_n.H_{2n+2}$. These chemists regarded the benzole and toluole, alleged to have been obtained by Schorlemmer, as *products* of destructive distillation and not properly educts of ordinary distillation. This statement, originally published by Schorlemmer, that benzole and toluole were obtainable by ordinary distillation from American petroleum has been copied and re-copied and has given rise to the popular error that the brilliant coal tar colors made from benzole and toluole could now be made in this country at prices with which foreign countries could not compete. The exhaustive analysis to which American petroleum has been frequently since subjected has failed to substantiate the fact. If found at all in American petroleum they are in very small quantities. Of course these hydro-carbons may be produced in the destructive distillation of some of the heavy varieties, but they are to be regarded as products and not as educts. Pelouze and Cahours obtained from American petroleum the following compounds:—

C_2H_6 . . .	gas.		
C_3H_8 . . .	gas.		
C_4H_{10} . . .	specific gravity	.600	
C_5H_{12} . . .	" "	.628	
C_6H_{14} . . .	" "	.669	
C_7H_{16} . . .	" "	.699,	boiling point 92° C.
C_8H_{18} . . .	" "	.726,	" " 116
C_9H_{20} . . .	" "	.741,	" " 136
$C_{10}H_{22}$ . . .	" "	.757,	" " 160
$C_{11}H_{24}$ . . .	" "	.766,	" " 180
$C_{12}H_{26}$ . . .	" "	.776,	" " 200
$C_{13}H_{28}$ . . .	" "	.792,	" " 218

About the same time that these investigations were being made in France, Mr. C. M. Warren was making an exhaustive examination in this country. In some respects they were confirmatory. He discovered the same compounds belonging to the $C_n.H_{2n}+_2$ series. In all, he succeeded in isolating fourteen different compounds, in considerable quantities, sufficiently pure, to allow of the separate distillation of either, without any material change in the boiling point. These fourteen compounds he classifies as follows:—

First Series.		Second Series.		Third Series.	
Formula.	Boiling point.	Formula.	Boiling point.	Formula.	Boiling point.
C_4H_{10}	?	C_4H_{10}	8.9°	$C_{10}H_{20}$	174.9°
C_5H_{12}	30.2°	C_5H_{12}	37.0	$C_{11}H_{22}$	195.8
C_6H_{14}	61.3	C_6H_{14}	68.5	$C_{12}H_{24}$	216.2
C_7H_{16}	90.4	C_7H_{16}	98.1		
C_8H_{18}	119.5	C_8H_{18}	127.6		
C_9H_{20}	150.8				

It will be noticed that the compounds included in the third series do not belong to the normal paraffine series

represented by the formula C_nH_{2n+2}. These belong to another group of hydro-carbons represented by the formula C_nH_{2n}. This is known as the ethane series or olefines.[1]

Messrs. Warren and Storer also examined Rangoon petroleum, in which they discovered a number of compounds of the olefine series, and also some of the paraffine series. These experiments would lead to the opinion that the heavier portion of the Rangoon petroleum belonged to the olefine series, while the light portions belonged to the paraffine series. The following is a list of the compounds, with their chemical formula and respective boiling points, obtained from Rangoon petroleum:—

Rutylene	$C_{10}H_{20}$	. . . . boiling point	175° C.
Margarylene	$C_{11}H_{22}$	. . . . " "	195
Laurylene	$C_{12}H_{24}$	. . . . " "	215
Cocinylene	$C_{13}H_{26}$	. . . . " "	235
Naphthaline	$C_{10}H_8$	. . . . " "	. . .

"Also probably pelargonene (C_9H_{18}), boiling at 155°, and members of one or both the series of hydrides (from American petroleum), it being a fair presumption that we had in our hands hydrides of oenanthyl (C_7H_{16}), of capryl (C_8H_{18}), and of pelargonyl (C_9H_{20}). Our experiments also indicate the probable presence of xylole and isocumole." It would thus appear from the analyses above detailed that petroleum contains hydro-carbons of more than one series. The American variety being almost entirely composed of the series

[1] It will also be observed, that the second series contains a number of compounds exactly similar in their chemical composition to compounds belonging to first series, yet differing in their boiling points.

represented by formula C_nH_{2n+2}, while the Rangoon, the Caucasian, and Gallician varieties contain both series, the olefines in notable quantity. As we approach the denser constituents of petroleum, the analysis becomes more difficult, and the divergency between the results of different experiments is more apparent. It is now thought that paraffine, which was supposed to be a homogeneous body, is a "mixture of several homologous, perhaps isomeric, bodies, having similar properties, but different boiling points."

Professor Henry Morton, of the Stevens Institute of Technology, has made some interesting experiments upon the "residuum" of the distillation of petroleum. Among other substances he isolated a compound, to which he gave the name of "*viridine.*" He thus speaks of it in his paper: "The crude tarry matter is well washed with benzine (petroleum naphtha), then with alcohol, and is lastly dissolved in coal-tar naphtha (benzole), filtered hot and crystallized out on cooling. It is then obtained as a mass of very minute needle-like crystals of a greenish-yellow color and pearly lustre in the mass. This I described under the name of viridine, in a paper read before the American Institute, in New York, and drew attention to the remarkable spectrum which its fluorescent light yielded, which resembled in a striking manner that of anthracene, while the crystalline forms, solubilities and fusing points of the two bodies were decidedly unlike." Professor Morton also expresses his belief that the substance does not "exist ready formed in the petroleum, or even in the petroleum tar,

but is, like anthracene for example, a product of destructive distillation at something like a red heat." "In 1876 Dr. H. W. C. Tweddle exhibited at Philadelphia a greenish substance that he called 'petrocene,' from which he obtained a yellowish-green substance which he called 'thallene.' This was the raw material of this research, the few killograms that were exhibited being obtained from 50,000 barrels of petroleum; the density of 'petrocene,' that is to say the crude material, is about 1.206. It was separated into lighter paraffines, having a density of about 0.990 and heavier hydro-carbons of about 1.27. Bromine and sulphuric acid separated from 5 to 15 per cent. of paraffine having a very high melting point, 70°, 80°, and 85° C.; ordinary paraffine melting at 65° C. The unsaturated hydrocarbons, anthracene, phenanthrene, chrysene, chrysozene, and pyrene were recognized. Organic analysis showed a hydro-carbon containing from 88 to 96 per cent. of carbon, which is a larger percentage than is found of coal, even anthracite rarely attaining 95 per cent."[1] Prof. Samuel P. Sadtler, of the University of Pennsylvania, in a letter dated November 4, 1881, thus details some interesting experiments made by himself:—

"Classifying the subject under the three heads of: 1, Gaseous products accompanying crude petroleum; 2, Crude petroleum; and 3, Solid products accompanying and derived from the petroleum, I started with the first. I made analyses of some ten lots of 'natural gas' taken from wells in different parts of the oil field, and representing different

[1] Prof. S. F. Peckam, U. S. Census Report, 1880.

geological horizons as far as possible. As there was some doubt as to whether the results of eudiometric analysis could indicate the presence of the higher members of the paraffine series, I supplemented these analyses by a series of absorption tests made on the spot. Thus I passed a current of natural gas for a time through absolute alcohol, which, while it does not dissolve hydrogen, absorbs marsh gas slightly, ethane, propane, and the higher hydro-carbons in increasing amount. The hermetically-sealed flasks of the alcohol were then examined in my laboratory, and the gases absorbed driven out by heat, and collected over mercury and analyzed. They proved to be chiefly ethane and propane. I also passed a current of the gas through bromine, both pure and alcoholic, so as to absorb the olefines. On after-examination in my laboratory by neutralizing the free bromine with soda and diluting, I succeeded in separating out colorless oily drops of ethene dibromide, and, presumably, though not certainly, propene dibromide. In the study of the liquid crude oils, after classifying the oils from the different geological horizons (with information given to me by Mr. John F. Carll), and noting gravities, colors, and other physical properties, I proceeded to classify them by filtration (as far as possible in the cold) with animal charcoal and with mineral materials, like clay, alumina, etc. I did this with a view of examining chemically and microscopically the coloring impurities thus withdrawn. My results with these portions withdrawn by filtration are very incomplete; still I think they are largely made up of the members of the higher and more condensed

hydro-carbon series, like anthracene, etc., and not simply amorphous carbon, as supposed by some chemists. In corroboration of this view, I may say that in the crude oils, picric acid will strike a deep blood-red color, like the color of its compound, with anthracene, fluorine, etc. Whereas, in the yellow oil, clarified in the cold by animal charcoal, no such result is obtained. I also verified with a number of crude oils Schorlemmer's observation, that olefines are present, capable of being withdrawn by bromine, and, in small quantities, members of the benzole series, capable of yielding nitro-derivatives like nitro-benzole and nitro-toluole. Indeed, taking several distinct fractions gotten from Bradford oil, I obtained in notable quantities, in the lightest fraction, light-yellow nitro-benzole, and in the higher fractions reddish-yellow nitro-toluole, and probably higher products. I also extracted paraffine from a number of the crude oils, by mixing several volumes of ether with the oil and then chilling, when almost all the dissolved paraffine will separate and can be filtered off.

"Lastly of the solid products which accompany petroleum I examined the paraffine of buttery or firmer consistence, which separates out on the tubing, or derrick-frames, in Bradford oil wells. This was dark in color, looking like the crude ozocerite of Galicia, but not so firm. It had all the characters of a paraffine mixture; I had also collected a whitish, buttery mass from several flowing wells, near Warren, Pennsylvania; this on examination proved to be a perfect emulsion of oil and water, which would stand for months, but separated into distinct layers of oil and water

when warmed. I also took up for examination the solids gotten from Pennsylvania petroleum by pyrogenic formation. Of this character were petrocene and allied products, first mentioned by Dr. Herbert Tweddle, and from which Prof. Henry Morton extracted thallene."

In a subsequent paper published by Professor Sadtler in summing up the results of his own and other observations he says: "What was the material used for these investigations? Were the crude petroleums examined by these different authorities exactly the same, or if, by chance, they ought to have been, are they to be compared with all other petroleums now known? Those familiar with the crude oils as produced in the different sections of Venango, Clarion, and Butler counties, and very recently in Warren and McKean counties also, will know that these oils vary in color from a light amber to a dark black, and in gravity from 30° to 55° Baumé, from thick lubricating oils to nearly pure benzene. Moreover, they come from very different strata or 'sand rocks' as they are termed. It will thus be seen that if we wish to study the chemical composition of petroleum thoroughly, we have a considerable body of material to choose from. The material must also be carefully assorted before any satisfactory study of petroleum can be made. The great bulk of the crude petroleum that is sent to the refineries, or is exported, is shipped by the pipe-line companies, which have their network of pipes ramifying through whole districts collecting the entire yield of a district and storing it in their immense

tanks. *To study such crude petroleums would be like analyzing the sweepings of a mineral cabinet.*"[1]

When we add to the difficulties, just described, in the way of a correct analysis of petroleum, the different amounts of heat employed in effecting the separation of the compounds found in it, also the impossibility of deciding in many instances whether these compounds are educts or products, we have some conception of the difficulties which beset the path of the investigator. In presenting the present aspect of the chemistry of petroleum, we have endeavored to survey the whole field in order to present in the briefest space possible what is really known respecting this highly complex body.

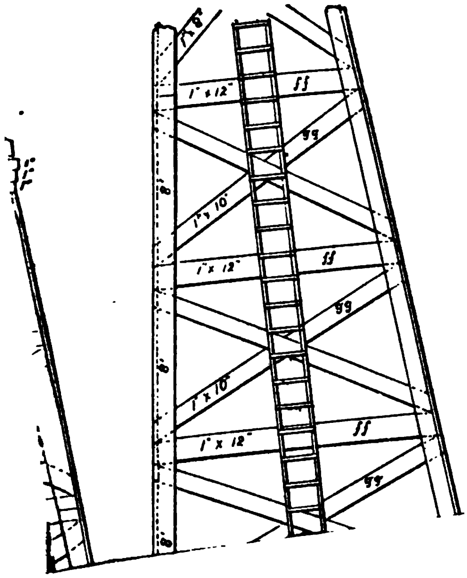
[1] United States Census Report, 1880, Prof. Peckam.

CHAPTER VII.

AMERICAN METHOD OF DRILLING FOR OIL.

It may be reasonably supposed that the experience gained in exploring the various oil belts by the thousands of wells which have been drilled, has resulted in the employment of the most approved methods. Ingenuity has been taxed to its utmost to supply the tools requisite to pierce the hardest rocks oftentimes a thousand or two thousand feet below the surface. While the general principles concerned in the operation and construction of the tools have not been materially modified, so many alterations and improvements have been made, that the process of well-drilling is quite a different affair from what it was in the early days of oil prospecting. Wells are now drilled in fifteen, twenty, or thirty days, that a few years ago would have required months to complete. The skill and ingenuity displayed by a professional well-driller in contending with and successfully overcoming the innumerable obstacles, mishaps, and break-downs that he meets with are simply marvellous and, to the uninitiated, almost incredible. This skill is the result of a quick intelligence, natural shrewdness, joined with a delicate sense of touch, a trained ear, and long and close observation. The tools which have

PLATE I.



been invented on the spur of the occasion to meet some unexpected difficulty, are to be numbered by the hundred. They are of all kinds and devices "from the delicate grab designed to pick up a small piece of valve leather, or a broken sucker rod rivet from the pump chamber, to the ponderous string of pole tools containing tons of iron, which, at a depth of 1500 feet or more, can unscrew a set of stuck tools, and bring them up piece by piece, or cut a thread upon the broken end of a sinker bar, or an auger stem, so that it can be screwed fast to and loosened by the use of 'whiskey jacks' at the surface."

The first step of an oil miner, after having located his well and made the necessary arrangements by purchase, lease, or royalty, for the territory on which the venture is to be made, is to make his contracts for what is termed the "carpenters' rig." This part of the expense comprises all the wood-work, over the mouth of the well, affording shelter for the workmen, and the appliances necessary to the convenient handling of the well-driller's tools.

The illustrations on Plate I[1] will enable a mechanic to construct a first-class rig, although he may never have seen an oil well. Fig. 1 (Plate I) shows the side elevation, Fig. 2 (Plate I) the end elevation, and Fig. 3 (Plate I) the horizontal projection. The most conspicuous part of

[1] This plate forms one of the illustrations of the Geology of the Oil Regions of Warren, Venango, Clarion, and Butler Counties, Pa., etc., by John F. Carll of the Second Geological Survey of Pennsylvania, and is here republished in reduced size through the courtesy of the Board of Commissioners of the Geological Survey. The description of the details with illustrations are from the same volume.

the arrangement is the derrick, Fig. 1 (Plate I), a feature in the landscape never out of sight in the oil regions. This is a tall pyramidal frame structure about 75 feet in height and 12 feet square at the base. Fig. 4 shows a plan of the foundation timbers of the rig. The dimensions of the timber depend very much on circumstances. While the illustration is drawn for sawed timber, it is generally cheaper to hew it from trees felled near the well, in which case it will necessarily vary somewhat in size. The mud sills *a*, which are generally sunk in trenches, have gains cut into them for the reception of the main sill *d* and sub-sills *e* and *e'*; *f* represents the derrick sills and *f'* the derrick floor sills. After all the timbers have been placed in their proper positions and levelled up, the whole foundation is firmly locked together by driving in the keys or wedges *h*.

The derrick stiles are connected by the girths *f f*, and braced by the diagonals *g g* at frequent intervals; *h h* is a ladder reaching from the base to the top of the structure; *g* represents the derrick floor, and *j* the corner-stones or blocks. The samson post *k* and the jack posts *l* and *s* and knuckle post *r* are dovetailed into the sills and held by keys *h*. The braces *k'* are set in gains and keyed up, no mortices or tenons being used in the structure. The derrick contains the bull wheel *b' b*, and crown pulley *j j*, and crown pulley block *j j'*, for hoisting and lowering the drilling implements; also the walking beam *y*, the band wheel *m*, and the sand pump pulley *i i*.

The engine *b'* is bolted to the engine block *b*, which rests upon the cross sills *a'*, and is braced by the brace *c*.

The steam-pipe *k k* connects the engine with the boiler. By means of the driving pulley, which carries the belt *o o*, motion is communicated to the band wheel *m*, and through it to all parts of the machinery. The throttle valve *l l* is operated by a grooved vertical pulley from which an endless cord or wire *m m*, called the telegraph, extends to the derrick and passes around a similar pulley, *n n*, fixed upon the headache post *z*, also called a "life preserver." As its name indicates, the headache post is designed to save the driller a headache, or perhaps his life in case the wrist-pin should break, or the pitman fly off of it, while drilling, thus causing the derrick end of the walking beam to drop under the great weight of the suspended drilling tools, and endangering the safety of all within reach. This post is set upon the main sill immediately under the walking beam, so that if such an accident occur, the walking beam can fall but a few inches and do no harm.

The pulley *n n*, and that fixed upon the headache post being thus connected, the movement of one communicates a like motion to the other, and the driller by placing his hand upon the derrick pulley can operate the throttle valve and start or stop the engine, and increase or decrease its speed at pleasure, without leaving his position. The reverse link *p p* is also operated from the derrick by the cord *q q*, which passes over two pulleys, one fixed in the engine house and the other in the derrick. The band wheel *m* receives its motion direct from the driving pulley of the engine to which it is connected by the belt *o o*. On, or near, the end of its shaft *o*, is the bull-rope pulley *n*, and to its other end is fastened the arm or crank *o'*. In this arm

a number of holes are drilled for the reception of the adjustable wrist-pin *p*, which thus may be easily moved from one hole to another to regulate the length of the stroke required in drilling or pumping.

As the band wheel communicates motion through the pitman *q* to the walking beam while drilling, to the bull wheels *b b*, by the bull rope *r r*, while running up the tools, and to the sand-pump reel by the friction pulley *w*, while sand-pumping, and as these movements are all used separately and at different times, it is necessary that the machinery be so constructed in its different parts that connection may be quickly made or broken, and one kind of motion substituted for another at pleasure.

The sand-pump reel *w* is put in motion by pressing on the lever *v*, which is joined by the connecting bar *u* to the upright lever *t*. This brings the face of the bevelled pulley *w* into contact with the face of the band wheel. It is simply a friction pulley and can be thrown in or out of gear, no matter at what speed the band wheel may be revolving.

Fig. 5.

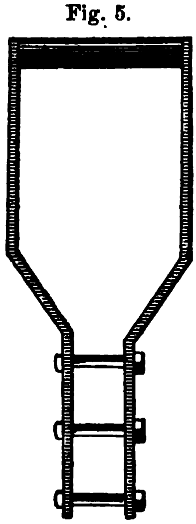
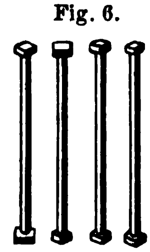


Fig. 6.



For a fuller illustration and explana-

tion of the details of Figs. 1 to 3, we annex figures representing a complete set of irons belonging to a carpenter's rig.

Fig. 5.—Walking-beam stirrup.

Fig. 6.—Bolts for securing this by a wooden cap to walking beam.

Fig. 7 and Fig. 7 *a.*—Boxes for band-wheel shaft.

Fig. 8.—Band-wheel shaft, arm and flanges.

Fig. 9.—Centre irons for walking beam and samson posts.

Fig. 10 and Fig. 10 *a.*—Bolts for securing the saddle to walking beam.

Fig. 11.—Derrick or crown pulley.

Fig. 12.—Walking-beam hook, to hold temper screw.

The next step in the operation is to place "a wooden conductor" through the earth and gravel down upon the bed-rock. The depth of the excavation necessary for this purpose varies of course according to the location of the well. The conductor (*i*, Fig. 1, Pl. I), is made of heavy planks spiked together, and must be carefully adjusted to the surface of the rock, to prevent the washing of the mud or gravel from entering the well at this point.[1] The build-

[1] Whenever the rock is at a considerable depth, recourse must be had to a somewhat different method of operating. A pit is dug under the derrick for some distance down, usually until the process is interrupted by the influx of water, a conductor or pipe of some kind is driven into the earth at the bottom of the pit and forced through to the rock by means of an instrument resembling a pile-driver. The pipe may be of wood or iron, generally an iron pipe is used, called a driving pipe. It is prepared in joints of a certain length, and the joints are connected as the pipe is driven into the ground. The opera-

Fig 7.

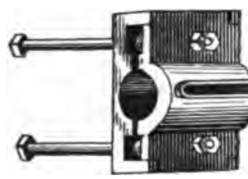
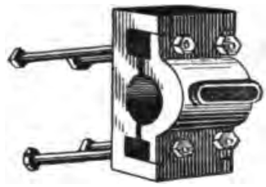


Fig. 7 *a*.



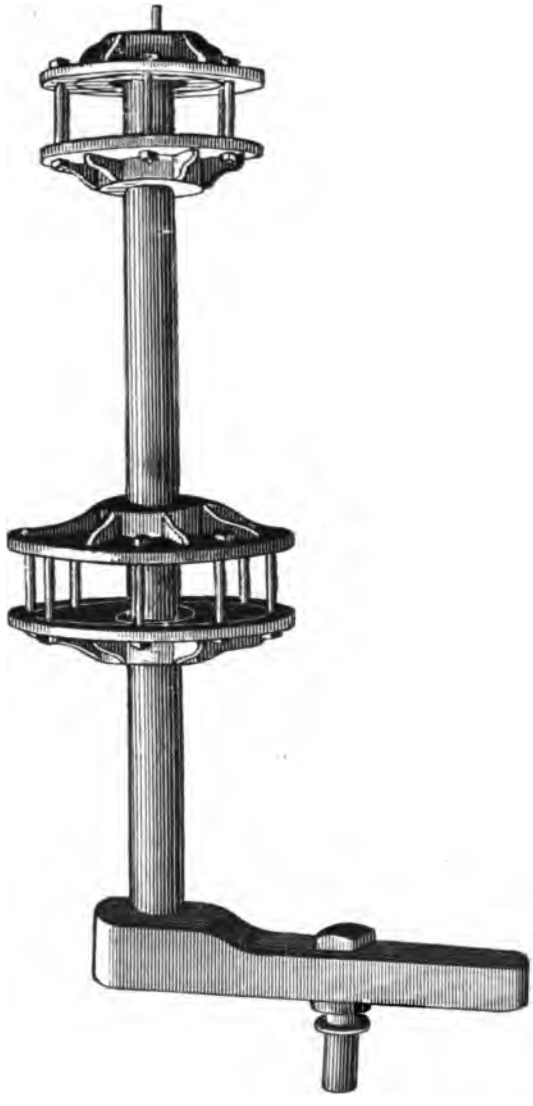


Fig. 8.

ing of the several joints of the conductor, and placing it in position frequently form part of the contract with the carpenter. The derrick having been placed in position, the boiler and engine having been set up, and the belt con-

Fig. 9.

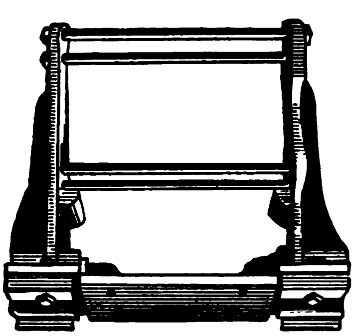


Fig. 10.

Fig. 10 *a*.

Fig. 11.

Fig. 12.

tion is generally successful, but frequently the pipe runs upon a large stone, and in some cases, is bent or deflected from a vertical course. The pipe, however, having been successfully put down to the solid rock, the earth is removed from the interior.

nection made between the latter, and the wheel within the derrick, the driller is ready to commence operations.

Fig. 13.

Fig. 14.

Fig. 15.

There are four principal tools, properly so called, used in the process, viz., the centre bit, the auger stem, the jars, and the sinker bar. In a well that is being drilled these tools hang in the order named, the centre bit being the lowest. This is a bar of iron (Fig. 13) a few feet long with a sharp steel cutting edge on the lower end. To this is attached the auger stem (Fig. 14), which is simply a round bar of 4-inch iron from 28 to 40 feet in length. Then come the jars, two peculiarly constructed pieces of metal so formed that, as indicated by their name, a sudden jar will be imparted to the tools at every upward and downward motion as the drilling progresses, serving to loosen the bit if by chance it should become wedged in the hard rock. The jars therefore form a very important portion of the drilling tools, being the connecting link between the drill and the means of operating it. Fig. 15 shows them closed, or with the upper wing resting upon the lower one, the improved rounded wing in front concealing the central slot from view, and Fig. 16 shows another pair where both wings are made alike and the links are open. The two sets are precisely alike in principle and vary only in details of construction. The fourth piece, to which is attached a long cable reaching up to the surface, is the sinker-bar (Fig. 17), resembling the auger stem, but only from fourteen to sixteen feet long, and used simply to give additional weight to the other tools.

Figs. 18 and 19 represent sections of the jars shown in Fig. 15.

The cable by which these tools are suspended in the

well passes up to the top of the derrick over the crown pulley previously spoken of, and down again to the bull

Fig. 16.

Fig. 17.

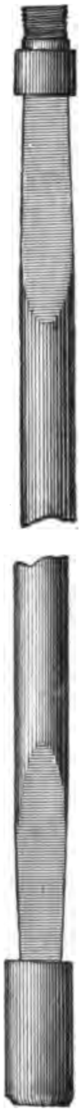


Fig. 18.

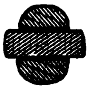
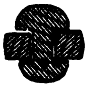


Fig. 19.



wheel at the foot of the derrick, around which it is coiled. By applying power to this wheel, the tools may be drawn up from the well and suspended on the derrick, as it is often necessary to do, to get at the bit to sharpen it. The tools are permitted to run back into the well by their own weight, a brake on the bull wheel controlling the motion. About eight or ten feet above the mouth of the well, the cable is fastened to one end of the walking beam oscillating on the samson post, connection being made at the other end of the beam with the engine. By this means a rising and falling motion is imparted to the tools, the impact of the centre bit on the rock drilling the hole. The rate of progress varies of course with the character of the rock. In early times perhaps ten feet a day was considered fair progress, but at present, with tools weighing about one ton and dropping a distance of two feet with every vibration of the walking beam, a very heavy blow is struck and rapid progress is made.

In drilling, the tools are lowered a little with every stroke by means of a temper screw (Fig. 20) manipulated by the driller. With the old-fashioned temper screw a great deal of time was spent in readjustment, for it had to be screwed up thread-by-thread by tedious revolutions of the clamps. But this delay is now obviated. The nut through which the screw passes is cut in halves, one half being attached to the left wing of the screw frame, the other half to the right wing. An elliptical band holding the set screw (Fig. 20 *a*) passes around the nut. It is riveted securely to one of the halves, and the set screw

Fig. 20.

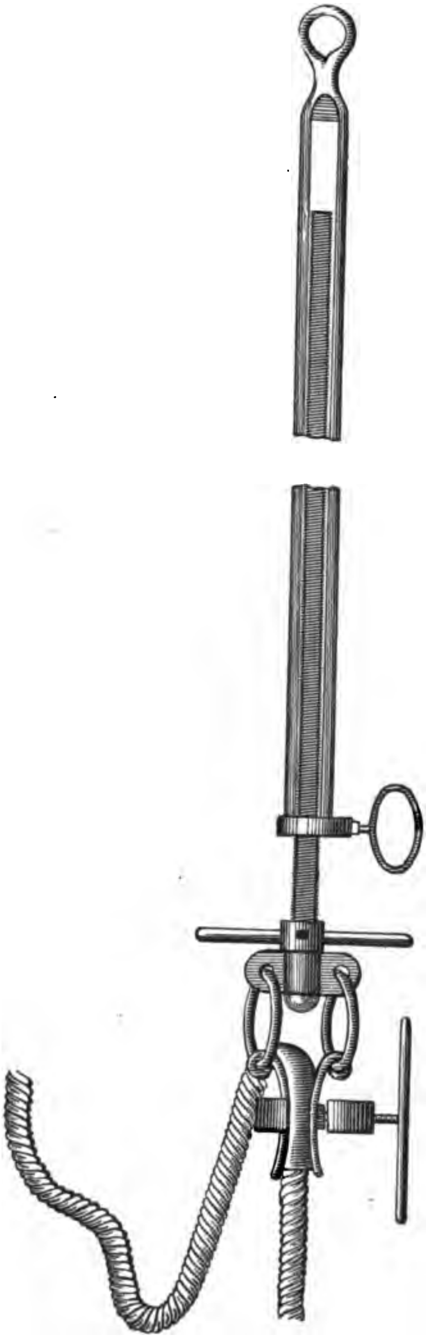


Fig. 20a.

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presses against the other half to keep the nut closed. The wings are so adjusted that they spring outward and open the nut whenever the set screw is loosened. To "run up" the screw, the driller clasps the wings in his left hand and loosens the set screw; he then seizes the head of the temper screw in his right hand, and, relaxing his grip upon the wings, the nut opens, when he quickly shoves the screw up to its place, and again grips the wings and tightens the set screw, the whole performance occupying less time than it has taken to describe it.

The *débris* resulting from the drilling operation is held in suspension at the bottom of the well, water being poured into the well for that purpose. When a considerable quantity of broken rock has accumulated, the tools are withdrawn, and a "sand pump" inserted, which removes the liquid mud and sand from the well. The sand pump descends into the well by its own gravity, and to prevent it from attaining a too great speed, it is checked by pressing the lever *v*, Fig. 1 (Plate I), backward so as to throw the friction pulley *w* against a post or curved piece of sheet iron set behind it in proper position to act as a brake when the wheel is pressed against it. The sand-pump line is coiled upon the shaft *x*, Fig. 1 (Plate I). It passes direct from the shaft over the pulley *i i*, and thence down inside the derrick to the well mouth, where it is secured to the bail of the sand pump.

Sometimes a tool called "a reamer" is inserted in place of the centre bit, which reams out the hole and removes

Fig. 21.

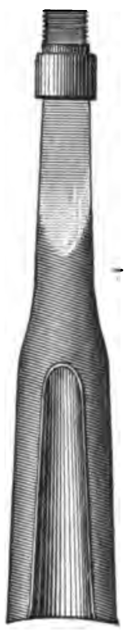
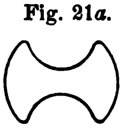


Fig. 21a.



any irregularities. The tool is shown in Fig. 21, and a bottom view of the same in Fig. 21*a*.

The ordinary drilling tools occupy a space of about 62 feet in length, and weigh when strung up about 2100 pounds. A complete set of improved drilling tools now employed costs about $700. Owing to the great length of these tools, before the regular drilling commences, as the walking beam cannot be got into operation, until the hole is deep enough to allow them to sink beneath the derrick floor, the driller has to resort to what is termed "spudding," that is, the hole must be made without the intervention of the walking beam. This is accomplished with the aid of a cable and the bull wheel. The driller, by dextrously coiling and uncoiling this cable at regular intervals, permits the auger stem to rise and fall into the well, forcing its way through the drift or stone. The process is somewhat slow, but as the distance to be accomplished by this expedient is comparatively small, it far more than counterbalances the additional expense and inconvenience of erecting a very high derrick. The work of placing in the drive pipe requires a great deal of judgment and skill. Sometimes as much as three hundred feet of this pipe has to be placed in position. When a sufficient depth has been attained to allow of the drilling tools to be "strung

up," the "spudding" ceases, and the work of adjusting the tools in position is in order—every part, every joint is inspected. Their united length occupies the space between the surface of the ground, and the crown pulley at the top of the derrick, and by means of the brake *c c*, Fig. 1 (Plate I), attached to the bull wheel, they are let down into the well, and the real work of drilling commences.

From this point downwards the daily routine of the work is very monotonous, unless some accident occurs to diversify it. Day and night the machinery is kept in motion. One driller and one engineer and tool dresser work from noon until midnight ("the afternoon tour"), and another pair from midnight until noon ("the morning tour"). Up and down goes the walking beam while the driller, with a short lever, inserted in the rings of the temper screw, walks round and round, first this way and then that, to rotate the drill. He watches the jar, and at proper intervals lets down the temper screw, as the drill penetrates the rock; when the whole length of the screw has been run out, or the slow progress of the drill gives warning that it is working in hard rock, and needs sharpening, he arranges the slack cable upon the floor so that it will go up freely without kinks, and informs the engineer that he is ready to draw out.[1]

At every interval of the drawing of the tools from the well for the purpose of sharpening the auger bit, it

[1] J. F. Carll, Geolog. Survey, Penna.

Fig. 22.

 SLATE OR SHALE.

becomes necessary to remove the detritus of the fragments of rocks, the gravel, and sand, which, if allowed to accumulate, would seriously impede the rate of progress; at this juncture the "sand pump" is introduced.

This is lowered in the manner already described, and, by its valvular construction, efficiently removes all the rubbish, after which the drilling is resumed. The above is a brief description of the process. We furnish to our readers a diagram of the operation (Fig. 22), which exhibits also the different strata through which the drill passes. These may be classified under three general heads: 1. What may be termed, the surface drift, composed, as before stated, of alluvial soil, beds of gravel, sand of loose texture. This division may have a depth of only a few feet in some places, in others, in the valleys, it may be two or three hundred feet thick. 2. The water-bearing rocks, at the bottom of which, where the drill has reached this point, a "seed-bag" packing is placed to prevent the inflow of water into the well. 3. The rocky strata in which little or no water is found. These comprise one thousand or fifteen hundred feet of the whole depth of the well. A well was dug at Titusville through 3300 feet of rock, where water had to be poured in at the top to moisten the drillings and allow of the working of the sand pump.

Cost of Drilling an Oil Well.

As might be anticipated from what has already been said, it is quite impracticable to estimate with entire accuracy what a well will cost, although in a certain district where previous drilling had pretty well defined the horizon of the oil-bearing sand, and the character and hardness of the different strata of that particular locality, contracts for the job will be readily undertaken by the professional driller. The following figures in detail were furnished as showing the cost of drilling a well in Bradford district, McKean County, in 1878.

Carpenter's rig complete	$350 00
Belt, bull-rope, engine-telegraph, water-pipe, steam-pipes, and fittings to connect boiler and engine	100 00
Boiler 20 horse-power, and engine 15 horse-power	750 00
Contract for drilling, contractor to furnish fuel, tools, cable, sand, pump-line, etc., at 65 cents per foot, say 1500 feet	975 00
Casing, say 300 feet at 80 cents per foot	240 00
Tubing, say 1600 feet at 20 cents per foot	320 00
Torpedo (almost universally used before tubing)	100 00
Packer	25 00
Working barrel	8 00
Casing head	3 00
"Tees" and "elbows" to make tank connections	5 00
One twenty-five barrel tank	25 00
One two hundred and fifty barrel tank	110 00
Tank house	25 00
Expense of tubing and packing well	20 00
Expense of hauling tubing and material, etc.	50 00
Total cost of well, flowing	$3106 00

In the above well no "drive pipe" was used, a short

wooden conductor set up by the rig-builder being all that was required. In localities where from 100 to 280 feet of drive-pipe casing costing $1.80 per foot are required, the cost of the well is increased accordingly. The above estimate is for a flowing well. If it has to be pumped, the appliances necessary for that operation will cost about $175.00 additional.

Both the cost and the time of drilling have been materially reduced since the early operations on Oil Creek, so much so, it is said, that the average cost to-day of a well 1500 feet deep is less than one of 500 feet in 1861. The time required to effect it has been reduced in like proportion. Very careful records have been kept of a number of wells, each day's progress accurately noted, and specimens preserved of the material through which the drill was passing.

Previous to the year 1875 no authentic records of the number of wells bored are available. Since that time great care has been taken to secure and regularly publish full details of every well, its depth, and its outflow of oil. We take from the 'Derrick's Hand-Book' the following facts which we have tabulated:—

		Producing wells.	Dry holes.
Wells drilled in	1876	2,319	329
" "	1877	4,056	657
" "	1878	2,988	373
" "	1879	2,798	141
" "	1880	4,203	143
" "	1881	3,848	167
" "	1882	3,263	178
" "	1883	2,949	263
" "	1884	2,195	256
		28,619	2507

The above table represents the number of wells completed in the years enumerated, and also the proportion of "dry holes" to the producing wells. Many of the "dry holes" are "wild-cat" wells, and were drilled purely for the purpose of exploration. Upon examination of the maps of the oil region there will be observed clearly defined outlines of the oil-producing sands, which may lie buried 1500 or 2000 feet below the surface. The outlines of these producing spots are only determined by industriously drilling, with an accurate record of the exact location of each well and the results obtained. This is expensive mapping, but it has been by such a process that we are furnished with this valuable information. It has been estimated that if the distance bored in search for oil within the limits of the territory above mentioned were measured in one direction, the earth would have been bored through its longest diameter twice over.

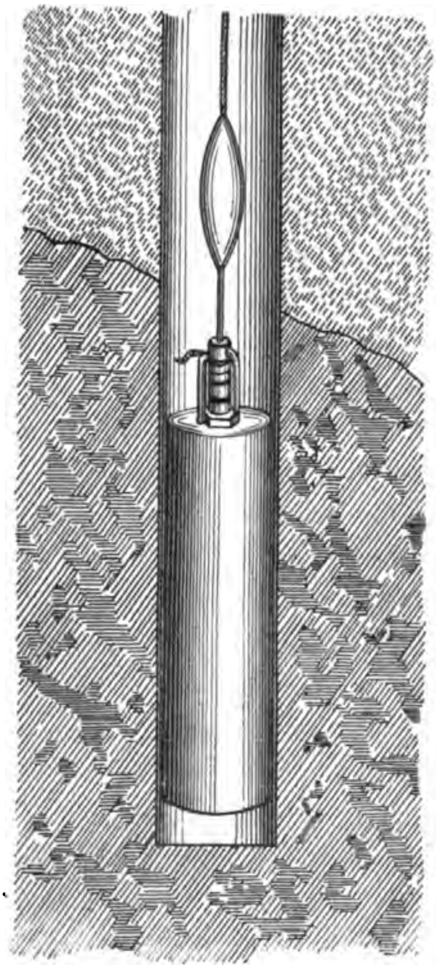
TORPEDOES.

The device of adding to the productiveness of oil wells by the use of explosives is wholly American. The idea was suggested and put into successful operation in the year 1862 by Colonel E. A. L. Roberts, then of the United States volunteer service. This theory at first met with but little favor. It was supposed that it would not only be unsuccessful as to practical results, but would damage and choke up any well in which it should be tried. Permission was given him in 1866 to experiment in the Woodin Well, a dry hole which had never produced a barrel of oil. The result of the operation was to secure a production of twenty barrels a day, and in the following month a second torpedo was tried, which brought up the production to eighty barrels. These results established beyond a doubt the usefulness of the invention, and immediately a demand for it sprang up throughout the oil region. The mode of operation in adding to the yield of oil is probably to be explained by the complete disintegration of the oil-bearing strata in the vicinity reached by the terribly explosive force of the nitroglycerine employed, by which the petroleum is set free from the thousand small cavities in which it has been confined. The method of employing the torpedoes is thus described: "When the well is ready to be 'shot,' word is sent to the Torpedo Company, and the canisters are prepared in sections of about ten feet in length and five inches in diameter. These sections are made conical at the bottom, so that they will rest securely on top of each other. The nitro-glyce-

rine is carried in cans, that are placed in padded compartments, in a light spring wagon, which is often driven over the roughest mountain roads with great recklessness. Arrived at the well, one of the sections is suspended by a cord that passes over a pulley and is wound upon a reel. The nitro-glycerine is poured into the canister until it is filled, and then it is lowered by the cord to the bottom of the well. Another section is filled and lowered in like manner, until the proper amount is put in place; then the cord is drawn up, and a piece of cast iron weighing about 20 pounds, and made of such a form that it will easily slide down the bore, is allowed to drop down upon the cap, which is adjusted to the last section that was lowered. At a depth of 2000 feet no sound reaches the surface, although 80 quarts of nitro-glycerine, equal to 2160 pounds of gunpowder, may have been exploded by the hammer. After from three to ten minutes have elapsed a gurgling sound gradually approaches the surface, and the oil welling up in a solid column, filling the bore hole, and mounting higher and higher, falls first like a fountain and then like a geyser, and forms a torrent of yellow fluid, accompanied by the rattle of small pieces of stone and fragments of the canister in a shower of oil spray 100 feet in height; in five or ten minutes it is all over; 25 or 30 barrels of oil have been thrown to the winds." Fig. 23 represents the torpedo in position. A flow of oil does not always follow the use of explosives. It has been found that in the productive sands of fine close texture they have little or no effect.

The most remarkable instance exemplifying the benefit of their use to be met with, I find in 'Taylor's Hand-book

Fig. 23.



of Petroleum, for the year 1884.' Independent of its interest in this connection, the author gives a most graphic

description of the successful drilling of the greatest "gusher" ever opened on this continent.

"October 27, 1884. Those who stood at the brick school-house and telegraph offices in the Thorn Creek district to-day and saw the Semple, Boyd & Amstrong, No. 2, torpedoed, gazed upon the grandest scene ever witnessed in oildom. When the shot took effect, and the barren rock, as if smitten by the rod of Moses, poured forth its torrent of oil, it was such a magnificent and awful spectacle that no painter's brush or poet's pen could do it justice. Men familiar with the wonderful sights of the oil country were struck dumb with astonishment, as they gazed upon this mighty display of Nature's forces. There was no sudden reaction after the torpedo was exploded. A column of water rose eight or ten feet, and then fell back again, and some time elasped before the force of the explosion emptied the hole, and the burnt glycerine, mud, and sand rushed up in the derrick in a black stream; the blackness gradually changed to yellow; then, with a mighty roar, the gas burst forth with a deafening noise; it was like the thunderbolt set free. For a moment the cloud of gas hid the derrick from sight, and then, as this cleared away, a solid golden column half a foot in diameter shot from the derrick floor eighty feet through the air, till it broke in fragments on the crown pulley, and fell in a shower of yellow rain for rods around. For over an hour that grand column of oil, rushing swifter than any torrent, and straight as a mountain pine, united derrick floor and top. In a few moments

the ground around the derrick was covered several inches deep with petroleum. The branches of the oak trees were like huge yellow plumes, and a stream as large as a man's body ran down the hill to the road, where it filled the space beneath the small bridge at that place, and continuing down the hill through the woods beyond, spread out upon the flats where the Johnson Well is. In two hours these flats were covered with a flood of oil. The hill-side was as if a yellow freshet had passed over it; heavy clouds of gas, almost obscuring the derrick, hung low in the woods, and still that mighty rush of oil continued. Some of those who witnessed it estimated the well to be flowing 500 barrels per hour. Dams were built across the stream, that its production might be estimated; the dams overflowed and were swept away before they could be completed. People living along Thorn Creek packed up their household goods and fled to the hill-sides. The pump station, a mile and a half down the creek, had to extinguish its fires that night, on account of the gas, and all fires around the district were put out. It was literally a flood of oil. It was estimated that the production was 10,000 barrels the first twenty-four hours. The foreman endeavoring to get the tools into the well was overcome by the gas and fell under the bull wheels; he was rescued immediately, and medical aid summoned; he remained unconscious for two hours, but subsequently recovered fully. Several men volunteered to undertake the job of shutting in the largest well ever struck in the oil

region. The packer for the oil-saver was tied on at the bull-wheel shaft, the tools placed over the hole and run in. But the pressure of the solid stream of oil against it prevented its going lower, even with the suspended weight of the two thousand pound tools; one thousand pounds additional weight was added before the cap was fitted and the well closed. A casing connection and tubing lines connected the well with a tank."

CHAPTER VIII.

NATURAL GAS, ITS ORIGIN—NATURAL GAS WELLS—CHEMICAL ANALYSIS OF NATURAL GAS—NATURAL GAS AS FUEL—PERMANENCY OF SUPPLY—NATURAL GAS AS AN ILLUMINATOR—NATURAL GAS AT PITTSBURGH.

ORIGIN OF NATURAL GAS.

ABOUT as many theories exist respecting the origin of natural gas as have been formed respecting liquid petroleum. It can hardly be said they have a common origin, although a variety of facts which are of easy demonstration point in that direction. The most generally received opinion, however, is that it is a product of the decomposition of organic matter deposited most probably in the mud of shallow seas of the Devonian period, and by its own expansibility finding its way through the cracks of superimposed strata, caused by the upheavals thereof familiar to the geologist.

Marsh gas, the chief constituent of "natural gas," being that hydro-carbon which contains the most hydrogen and the least carbon, is the necessary residuum of the abstraction of the carbon from organic matter by some oxidizing agency at a moderately low temperature in the presence of water. There are few, perhaps, who have failed to notice its presence on the surface of stagnant pools, as it collects and forces its way upward in bubbles. If the mud

beneath is stirred with a stick it will become disengaged in quantities, which will readily ignite if a flame be applied. A glass jar filled with water and inverted over such a locality may be readily filled with this "marsh gas" and removed to the laboratory for analysis or experiment. We have only to conceive of such "organic mud deposits" of great depth and extent, of their subsequent burial, of their alternate depression and upheaval through successive geological periods, and of their subjection to the internal heat of the earth, and we may have a fair idea of the origin of the immense volumes of this gas which now seek an exit through the upper crusts by a thousand openings. The immense force with which it sometimes finds a vent through some artificial boring, is due perhaps to the two causes which are ever present, to wit, the internal heat of the earth causing an expansion in volume, and, secondly, the hydrostatic pressure due to bodies of water counteracting to lessen this expansion. An opening made into a fissure in the earth, containing gas subjected to the forces above mentioned, and under the circumstances described, would at once relieve this pressure by the escape of the gas.

Natural Gas Wells.

The issue of inflammable gases from the earth in various parts of the world is no new phenomenon. Wherever wells have been bored for petroleum or for the manufacture of salt, carburetted-hydrogen gas has been observed to flow

in greater or less abundance. On account of its close local association, as well as its near relation chemically, it is very appropriately noticed in this connection. The recent important developments of natural gas in the vicinity of Pittsburgh and its extensive adaptation in various branches of manufacture render it desirable that a careful review of the subject should be furnished. For more than fifty years the gas which issues from the salt wells of the Kanawha Valley, West Virginia, has been employed as a fuel in the evaporation of the brine. In many salt mines the gas issuing from the crevices is utilized to light up the workings. The Chinese have thus employed it for centuries. In one province (Sze Chuen) it has been brought to the surface in pipes of bamboo from beds of rock-salt situated 1500 feet below the surface. They employed it for illuminating purposes long before the manufactured product was employed by European nations. It is also a constant and dreaded associate of the coal-miner in the shape of "*fire-damp.*" On the upper Cumberland, in Kentucky, gas accumulates in subterranean reservoirs in such quantities that large bodies of rock and earth are blown out with great violence, combining sometimes the phenomena of both earthquake and volcano. On the borders of the Caspian Sea, in the vicinity of Baku, this gas is observed to issue from the earth wherever a hole is dug only a few feet. In this place it is no uncommon thing for the traveller upon pitching his tent for the night to depend altogether upon this natural gaseous fuel to cook his evening meal, and, at the same time, to light up his temporary habi-

tation. Lime is burnt in the same district by simply building up around an opening thus made a quantity of limestone and setting fire to the flowing gas. By drilling deeper more copious and permanent supplies are obtained, which are utilized as fuel in a variety of ways—in the distillation of petroleum and for other purposes. In some districts of the oil territory of Western Pennsylvania, gas escapes from nearly every boring made, and was at one time a most serious annoyance to the oil men, and a great barrier in the way of a successful "strike." In Knox County, Ohio, in 1860, two wells were bored for oil at the same geological horizon as that which furnishes the oil on Oil Creek, Pa. At the depth of six hundred feet in each well a fissure was reached from which the gas issued with such volume and force as to throw out of the wells, to a considerable height, the heavy iron tubes used for drilling. One of these wells was tubed so as to exclude the water, and the gas continued to flow for more than five years with such force through a two and a half-inch iron pipe that the sound might be heard for a considerable distance; no accurate measurement of the quantity of gas thus escaping from the well was made, but it was estimated to be sufficient to light a large city. At West Bloomfield, New York, another well was bored, reaching down five hundred feet to the vicinity of the Marcellus bituminous shales, from which the gas issued with great force. At Erie, Pa., at Conneaut, Painesville, and Cleveland, Ohio, a number of wells have been successfully bored for gas, At Buffalo, New York, a well was sunk to the depth of 640 feet, when

a volume of gas of remarkable purity issued with a pressure of 130 pounds to the square inch. At Cumberland, Maryland, a well was bored for the purpose of obtaining oil; gas was struck and soon accidentally set on fire, and continued to burn for a period of two years. The gas of this well was successfully utilized in the manufacture of lampblack for printer's ink. The following description of a remarkable "burning well" is given by Mr. J. T. Henry: "Some six miles east of Crab Orchard, in Lincoln County, Kentucky, there is a spring known as the Burning Well, situated at the base of the Cumberland Mountains, on the banks of a small stream called Dix River. The water in this well is in a constant state of ebullition, and regularly every day between four and five o'clock in the afternoon overflows; a large quantity of gas is liberated, and, if a torch is applied, a flame results. The peculiar feature of this well is the diurnal and infallibly regular overflow." A periodicity regarding the flow both of oil and gas has been frequently observed, and is easily accounted for by the laws of hydrostatic pressure. An oil well was observed to flow for a considerable length of time with great regularity six days in the week and ceased to flow on Sunday; after this day of rest it commenced to flow again.

At Fairview, Pa., a well was drilled for oil in 1872 to the depth of 1335 feet. An immense volume of gas escaped through a six-inch pipe with so much noise that it could be heard for a distance of two miles; the pressure indicated eighty pounds to the square inch. The gas of this well was employed in a number of establishments in Fairview,

Petrolia, Kerns City, and Argyle, and it furnished fuel for drilling some forty other wells. Another remarkable well was bored in the same year near Titusville, Pa., from which, according to the best calculations that could be made, there flowed four million cubic feet of gas per day. At East Sandy, in the Pennsylvania oil region, a gas well was struck in 1869. It caught fire and resisted all efforts to extinguish it. It burned for a little more than a year, lighting up the surrounding country for some distance. The rush of gas and flame, roaring like a cataract, could be heard for miles. A paper read October 15, 1884, before the American Gas Light Association at Washington, D. C., gives the following account of the gas well at Freedonia, New York.

"In the year 1821 a gas spring was discovered near this village. No effort was made at that time to drill, but the gas collected by excavating and covering the spring was conveyed into a small copper holder. It was thence conducted through a pipe to a mill and several stores for illumination. It was introduced into a few of the public places, among which was the hotel that then occupied the site of the Taylor House, and which was thus illuminated when Lafayette passed through the village in 1824. The gas so used at that time was the first used in the United States, and the gas works established here were the first in this country. The spring from which gas was at first used is located on the north bank of the Canadaway Creek, at the bridge crossing the stream on the main street in the village. The gas escaped in various places in the imme-

diate vicinity, but when the well was sunk, it was concentrated in one opening. The gas from this well, which was sufficient for thirty burners, was used alone for thirty-seven years, when another was sunk on the creek in the northwest part of the village, the shaft being thirty feet deep, six feet in diameter at the top, and fourteen feet at the bottom with two vertical borings, one of one hundred feet and one of one hundred and fifty feet in depth. In the year 1858, a company was formed, and gas in sufficient quantity to supply 2000 cubic feet per day was conducted to the village through pipes. In 1859 a gas-holder, with a capacity of 12,000 cubic feet, was erected, and private families supplied.

Chemical Analysis of Natural Gas.

Natural gas, like petroleum, is a complex mixture of hydro-carbons, most of which belong to the series known in chemistry as paraffines. It is not, however, to be considered in the light of a petroleum vapor, which upon a slight reduction of temperature is reduced to a liquid. In composition also it differs greatly from the gas made from petroleum through the intervention of the red-hot gas retort, by which this oil is broken up into quite a different series of hydro-carbons, and forming a gas possessing the greatest illuminating power yet obtained. The vapors of these compounds are heavier in proportion to the amount of the carbon element.

The main ingredient of natural gas is marsh gas, which

next to hydrogen gas is the lightest substance known. It is the lowest in the series of hydro-carbons, *i. e.*, it contains the lowest percentage of the carbon element, and possesses greater calorific power than any of them. When pure, it is perfectly odorless and colorless. In Nature it is, however, generally associated with other gaseous compounds, or has a foreign odor imparted to it in its passage through different earth strata.

Its chemical symbol is CH_4, and it contains, approximately, 75 per cent. of carbon and 25 per cent. of hydrogen. Its specific gravity is 0.5576. The next in the paraffine series to which marsh gas belongs, and its almost constant associate, is ethyl-hydride (the chemical symbol of which is C_2H_6), containing 80 per cent. of carbon and 20 per cent. of hydrogen; specific gravity 1.043. The extraordinary progress made in synthetical chemistry of later years would lead us to hope that ethyl-hydride, or ethane, may be the point of departure for the formation of a great number of useful compounds, such as alcohol, chloroform, acetic acid, and glycerine. Neither of these substances has yet been synthetically produced, chiefly on account of serious technical difficulties due to the remarkable resistance to ordinary chemical reagents, which all the compounds of this series present.

Carbonic acid is likewise a constant ingredient of natural gas. The chemical symbol of this compound is CO_2; it is rather a diluent of the natural gas, and will extinguish a flame instantly if plunged into it. Carbonic oxide, symbol CO, is a frequent, but not constant, component of natural

gas. This gas contains one atom less of oxygen than carbonic acid, and is always a product of the imperfect combustion of carbon. Nitrogen has been found in the gas of several wells; it is in small proportion. Finally, the all-pervading gases, oxygen and hydrogen, the latter in an uncombined state, and frequently constituting a considerable percentage of the natural gas, have also been noticed as constituents.

A careful analysis of the gases of a number of wells has been made and a record of the same preserved. For a tabulated statement of these, taken from various published sources, the author is indebted to a report (published in pamphlet form) made "by a committee on natural gas to the American Society of Mechanical Engineers, May 21, 1884."

Table of Analyses of Natural Gas—from various sources.

CONSTITUENTS.	1 Petrolia, Canada.	2 West Bloomfield, N. Y.	3 Olean, N. Y.	4 Fredonia, N. Y.	5 Pioneer Run, Venango Co., Pa.	6 Burns's Well, near St. Joe., Butler Co., Pa.	7 Harvey Well, Butler Co., Pa.	8 Cherry Tree, Indiana Co., Pa.	9 Leechburg.	10 Creighton.	11 Penn Fuel Co.'s Well, Murraysville.	12 Fuel Gas Co.'s Well, Murraysville.	13 Roger's Gulch, Wirt Co., W. Va.	14 Gas from Marsh Ground.	15 Baku, on the Caspian Sea.	16 Gas occluded in Wigan Cannel Coal.	17 Blower in Coal Mine, South Wales.
Hydrogen	Chiefly marsh gas with ethane and some carbonic acid.	......	......	A mixture of marsh gas, ethane, and butane.	Chiefly propane, with small quantities of carbonic acid and nitrogen.	6.10	13.50	22.50	4.79	......	Marsh gas, with a little carbonic acid.	19.56	Chiefly marsh gas, with small quantities of nitrogen and 15.86 per cent. carbonic acid.	......	0.98	......	......
Marsh gas		82.41	96.50			75.44	80.11	60.27	89.65	96.34		78.24		47.37	93.09	80.69	95.42
Ethane		......	......			18.12	5.72	6.80	4.39	......		......		......	......	4.75	......
Propane		......	......			trace.	......	......	trace.	......		......		......	......	......	......
Carbonic acid		10.11	......			0.34	0.66	2.28	0.35	3.64		......		3.10	2.18	6.44	0.60
Carbonic oxide		......	0.50			trace.	trace.	trace.	0.26	Trace of heavy hydro-carbons.		......		......	......	......	......
Nitrogen		4.31	......			......	......	7.32	......			......		49.39	0.49	8.12	3.98
Oxygen		0.23	2.00			......	......	0.83	......			2.20		0.17	......	......	......
"Illuminating Hydro-carbons"		2.94	1.00			......	......	......	0.56			......		......	3.26	......	......
		100.00	100.00			100.00	99.99	100.00	100.00			100.00		100.03	100.00	100.00	100.00
Specific gravity		0.698	0.692			0.6148	0.5119		0.5580	0.5923	0.56						

1. Fouqué, Comptes Rendus, lxvii. 1045.
2. H. Wurtz, Amer. Journ. Arts and Sci. (2), xlix. 336.
3. Robert Young.
4. Fouqué, Comptes Rendus, lxvii. 1045.
5. " " " " "
6. S. P Sadtler, Report L., 2d Geol. Sur. Pa., 153.
7. " " " 3d " " 152.
8. " " " " " " 153.
9. " " " " " " "
10. F. C. Phillips.
11. Robert Young.
12. Rogers.
13. Fouqué, Comptes Rendus, lxvii. 1045.
14. Bischof's Chemical Geology, i. 730.
15. " " " "
16. J. W. Thomas, London, Chem. Society's Journal, 1876. 793.
17. " " " " " " 1875, "

Upon a careful examination of this table, it will be observed that while a few of the Ethyl series are to be found as constituents of natural gas, many more are wanting. It has been conjectured that in the lower sand rocks of the oil regions all of the members of this series may be found. Marsh gas may, therefore, be considered the chief element, carrying along with it a few other permanent gases, and also some of the lighter vapors of liquid petroleum which are generally deposited upon a reduction of temperature. The usual specific gravity of the natural gas is a little more than half that of common air. From the examination which was made it may be fairly concluded that the gases obtained from the deeper strata are of a higher specific gravity, are richer in the carbon element, and possess greater illuminating power.

A comparison between the "natural gas" and that manufactured from ordinary bituminous coal, for illuminating purposes, is best illustrated by placing in juxtaposition an analysis of each. We have selected the gas from the Leechburg well and the gas from cannel coal.

Leechburg Well.	
Hydrogen	4.79
Marsh gas	89.65
Ethane	4.39
Propane	a trace
Carbonic acid	0.35
Carbonic oxide	0.26
Nitrogen	...
Oxygen	...
Illuminating hydro-carbons	0.56
	100.00

Gas made from Cannel Coal.	
Hydrogen	27.7
Marsh gas	50.
Carbonic oxide	6.8
Olefiant gas	13.0
Nitrogen	0.4
Carbonic acid	0.1
Aqueous vapor	2.0
	100.00

The item of "olefiant gas" in the analysis from cannel coal includes under one head the whole amount of the "heavy hydro-carbons" which impart richness and luminosity to the manufactured gas. The gas made from petroleum, when allowed to pass in a fine stream into a retort, previously heated red-hot, is particularly rich in these heavy hydro-carbons, as the following analysis exhibits:—

Heavy hydro-carbons	33.4
Light hydro-carbons	40.—
Hydrogen	26.—

The specific gravity of this gas is 0.7. It has been estimated that 200 feet of this gas are equal in illuminating power to 1000 feet of gas made from coal, and it is so rich in the light-bearing element, carbon, that burners of special construction are needed in its use. On this account, in the manufacture of gas for illuminating in cities, small quantities of petroleum are sometimes used to impart richness to the product.

In the manufacture of gas from coal, there come over the luminiferous constituents and the non-luminous supporters of combustion. The former include the hydro-carbon gases acetylene, olefiant gas, butylene and vapors of the benzole and naphthalene series; while the latter embrace hydrogen, marsh gas, and carbonic oxide.

The chemist, Berthelot, made some experiments which are interesting in this connection. Formerly, it was the custom to regard the proportion of heavy carburetted-hydrogen (olefiant gas) as the measure of the illuminating power of gas. This chemist has shown, that in some samples of

good luminous power, the proportion of olefiant gas is very small. They contain, however, from 3 to 4 per cent. of benzole vapor. It has been shown that a mixture of one volume of hydrogen and three volumes of ethylene yields only a little more light than pure marsh gas, while hydrogen when mingled with only 3 per cent. of benzole vapor will give a brilliant flame.

The following table exhibits the various hydro-carbons, both gaseous and liquid, which are found either as components of, or are associated with, natural gas.

Table showing the Properties of the chief Gaseous Elements of Natural Gas, and including some of the heavier Hydro-carbons.

Paraffins.	Condition.	Composition.		Specific gravity of vapor.	Heat units yielded by 1 lb. in burning.	Cubic feet of air theoretically needed to burn 1 cubic foot of vapor.
		Per cent. Hydrogen.	Per cent. Carbon.			
Marsh gas	Gas	25.04	74.96	0.5576	13,370	9.56
Ethane	Gas	20.05	79.95	1.043	12,469	16.74
Propane	Gas	18.22	81.78	1.522	12,145	23.92
Butane	Gas, liquefies at 34° Fahr.	17.28	82.72	2.007	Not yet experimentally determined for the higher members.	31.10
Pentane	Liquid, boils at 100° Fahr.	16.71	83.29	2.49		38.28
Hexane	Liquid, boils at 158° Fahr.	16.32	83.68	2.97		45.45
Heptane	Liquid, boils at 210° Fahr.	16.04	83.96	3.46		52.63
Octane	Liquid, boils at 255° Fahr.	15.83	84.17	3.94		59.80

Natural Gas as Fuel.

The recent improved methods for the utilization of coal as fuel by conversion into a gas before its introduction into the furnace, have opened the way for the use of natural gas

into a great variety of industries. The great superiority of the improved method along with its economy prepared the minds of manufacturers to give this new form of fuel a fair trial. An analysis of the natural gas incontestably disclosed its great calorific power. The only obstacle in the way of its rapid and universal introduction was the uncertainty respecting the continued flow of the gas from the wells. As the alteration of the furnaces, to fit them for using the gas, often involved a large expenditure, it was reasonable to expect hesitancy in making the necessary changes. Its great advantages, however, in convenience of application, and its cheapness in comparison with every other form of fuel, gradually overcame every obstacle. Probably nowhere, has more attention been given to the scientific investigation of the subject than in the city of Pittsburgh, and certainly no more appropriate or more extensive field of operation could have been found. Natural gas, next to hydrogen, is certainly the most powerful gaseous fuel, and, when properly applied, the most economical, as we can obtain from it nearly all its theoretical heating power. In the manufacture of iron, its freedom from sulphur makes it peculiarly desirable as a fuel. The regularity of its supply under boilers makes the generation of steam an easy and certain thing, an important factor in the regulation of machinery. A committee of the American Society of Mechanical Engineers, to which the subject of the employment of the gas as a fuel was referred, recently made an interesting report to which we are indebted for valuable information. From this report we make the following extracts:—

Table showing comparative Effects of different Gas Fuels.

	Heat-units yielded by 1 cubic foot.	Number of cubic feet needed to evaporate 100 pounds of water at 212° F.
Hydrogen	183.1	293
Water gas (from coke)	153.1	351
Blast-furnace gas	51.8	1038
Carbonic oxide	178.3	313
Marsh gas	571.0	93.8

"A large number of experiments have been made to ascertain the value of gas in comparison with coal, but as yet the method of delivery of the former and its mode of application are so crude that any accurate results have not yet been reached.[1]

"Consumers are not charged according to the number of cubic feet delivered, and no meters are employed. Previous estimates having been made as to the cost of coal in the manufacture of one ton of iron, gas is offered to the manufacturer at a price which will materially reduce his fuel bill and render it more economical in other ways for him to use it. Accordingly his bills are rendered to him, not *according* for the amount of gas consumed, but according to the output of the furnace. With this method of delivery of the gas it is hardly likely that manufacturers will study economy in its use, or go to much expense in the scientific adaptation of their furnaces with this end in view. It is to be hoped, however, that a better, wiser system will be adopted, which will remedy a reckless waste

[1] [Since the appearance of this report, such substantial improvements have been made in these particulars, that these statements must be materially modified.]

of this valuable natural product. When it can be shown that by a simple contrivance of easy application, a factory could accomplish the same amount of work with the consumption of one-third of its present supply, consumers could not reasonably object to some form of meter being placed in their establishments provided rates were not increased. It is also quite reasonable to suppose that a more perfect and better regulated supply could be furnished at even less than present rates, which of course would in its turn invite a still larger demand.

"In the estimation of the calorific power of any form of fuel, its chemical analysis is absolutely essential. The next thing to be considered, after obtaining the theoretical amount of oxygen necessary to obtain perfect combustion, is to arrange for the proper supply of atmospheric air. In the use of coal the frequent opening and closing of the furnace doors vitiates any calculation in this direction, and while the difficulties in this respect are greatly lessened by the use of gaseous fuel, it has been found in practice difficult so to adjust the pressure and flow of the gas as at all times to mingle it with just the proper amount of air to insure perfect combustion."[1]

Mr. Metcalf, of Pittsburgh, makes the following sensible observations on this head:—

"There are three ways of getting at this combustion. The first is on the blowpipe principle with a strong blast of cold air and a heavy pressure of gas. This is a favorite and a stupid way. The second is what might be called

[1] [*Vide* foot-note, page 217.]

the blowpipe regenerative plan, by the use of a strong flow of gas and a steam or other blast driven through the air flues of a regenerative furnace. This produces a furious fire that is pretty to look at, good to stand away from, and which must be difficult to work with, besides being very destructive. The third is the regenerative plan, pure and simple; it consists in relieving the gas from pressure, increasing its volume, splitting it up, so that air can get to it, and then mixing it with a sufficient quantity of air as hot as can be made. The slower and lazier the movements of the gas and air the better, and the result is a beautiful soft, intense heat, that gives us the greatest amount of work with the least wear and tear. These methods are paralleled in using coal by the reverberatory style, the blast style, and the regenerative gas style. Except for the necessary use of blast furnaces the regenerative gas system is incomparably ahead of the others both in efficiency and economy.

"Notwithstanding the doubts of the so-called conservative men, it is a fact that 2240 pounds of muck-bar can be made in this way with fifteen bushels of slack; and the record of a whole year's run, including the drowning-out by floods and the falling out of large quantities of very thin steel scraps shows that by the most adverse figuring the cost of fuel per 2240 pounds of product could not be made up to quite sixty cents, and the natural gas men positively refused to include that furnace in an offer to furnish gas for the fuel bill, because they were getting more than twice that sum from the iron mills for their puddling furnaces. If then by the indirect and expensive process of splitting up

solid coal in a gas producer into a gas of the average composition of 70 per cent. nitrogen, 10 per cent. carbonic acid, and 20 per cent. carbonic oxide, we can obtain the great economies which we have already secured, we ought certainly to be able to do much better with natural gas, which is all combustible. To change a regenerative furnace over to the use of natural gas is a very simple matter; it is only necessary to use one-fifth of the volume required of producer gas to relieve it of pressure, split it up and mix it with five times as much air per volume as the producer gas required. This air is obtained in a continuous regenerative furnace by supplying the one-fifth volume of natural gas to the gas ports and using the ordinary supply of air; the equation then reads: Producer gas (one-fifth combustible) + air, one-fifth natural gas (all combustible) + air. Practice shows that that equation is wrong, and the expression should be: Producer gas + air, less than one-fifth natural gas + air, because there is a large gain in effective heat due to the absence of the four-fifths of non-combustible gases which the producer makes, and which have to be kept up to the temperature of the furnace. In the Siemens regenerative furnace, the natural gas is applied cold into the ports, and all of the chambers are used for heating the air. This looks like a perfect arrangement and it comes very near it in our present state of knowledge, but it is conceivable, if not possible, that an absorbent of nitrogen might be discovered, which would allow us to have a supply of pure oxygen to apply to our natural gas that would make combustion perfect."

All of these different modes of burning natural gas may be seen in operation in the city of Pittsburgh.

As may be supposed, invention is now being severely taxed to discover the most efficient and economical method of burning this gas. The results of a number of average tests show—

1. Compared with coal gas, natural gas exceeds it in calorific value, $33\frac{1}{3}$ per cent.

2. With crude, ordinary, and best method of combustion, the calorific value of natural gas compared with coal under best condition is—

With crude method, 20 cubic feet = 1 pound of coal.

With ordinary method, 11.29 cubic feet = 1 pound of coal.

With best method, 8.92 cubic feet = 1 pound of coal.

3. The value of 1000 cubic feet of natural gas compared with coal at $1 per ton of 2000 pounds is—

With crude method of carbonization, 2.5 cents.

With ordinary method of carbonization, 4.43 cents.

These careful tests of the calorific power of gas were made, first, by measuring the number of cubic feet required under ordinary conditions to evaporate a certain number of pounds of water. These experiments were made by Mr. C. E. Hequembourg, of Bradford, Pa., using a boiler 14 feet long, 62 inches in diameter, and having 96 three-inch flues. With this boiler he made a number of six-hour tests, using gas for fuel under all sorts of conditions: then reversing the firing conditions by substituting coal. As a result of these experiments, he found that

he could evaporate 8.55 pounds of water with one pound of coal; the same quantity of water was evaporated with 67.97 cubic feet of gas. A test of a similar character in another establishment went to show that the calorific effect of a ton of Pittsburgh coal equalled that resulting from the consumption of 22,000 feet of Butler gas. With coal at $1 per ton (Pittsburgh price) the gas might be estimated as costing 4½ cents per 1000 feet, other estimates make it between 7 and 8 cents per 1000 feet. The committee of engineers referring to some experiments, made under their supervision, make the following observations:—

"As the introduction of natural gas in this city has been of such recent date, most of its users consume it in such a crude manner that they fail to get the best results, the difficulty being the expense of making the necessary changes in the burning. There is, however, one notable exception among the large consumers, namely, the Union Iron Mills of Messrs. Carnegie, Bros. & Co., where it is being used with economy in Siemens' regenerative furnaces.

"An experiment was made to ascertain the value of gas as a fuel in comparison with coal in generating steam, using a tubular boiler of 42 inches diameter, 10 feet long, with 4 inch tubes. It was first fired with selected Youghiogheny coal, broken to about 4-inch cubes, and the furnace was charged in such a manner as to obtain the best results possible with the stack which was attached to the boiler. Nine pounds of water evaporated, to the pound of coal consumed, was the best result obtained. The water was measured by two meters, one on the suction, the other

on the discharge. The water was fed into a heater at a temperature of from 60° to 62°. The heater was placed in the flue leading from the boiler to the stack in both coal and gas experiments. In making the calculations the standard 76-pound bushel of the Pittsburgh district was used, 684 pounds of water were evaporated per bushel, which was 60.90 per cent. of the theoretical value of the coal. When gas was burned under the same boiler, but with a different furnace and taking a pound of gas to be equal to 23.5 cubic feet, the amount of water evaporated was found to be 20.31 pounds, or, 83.40 per cent. of the theoretical heat-units were utilized."

The advantages resulting from the use of a fuel so cheap, pure, and easily managed, cannot be over-estimated. In the manufacture of glass, it has been found to be especially valuable. Its freedom from dust, ashes, etc., has improved the quality of the product. One of the great difficulties in the manufacture of glass has been that of properly regulating the heat during the annealing process. This difficulty is removed almost entirely by the regular and graded flow of gas. By this means glass of a really superior quality can be furnished, as the molecules composing it come to their normal positions without strain. This is due to the complete control which is maintained over the heat during the gradual process of annealing the glass.

Natural gas appears to be applicable as a fuel to nearly every purpose where coal has been used hitherto. Success, however, has not followed its use for smelting ores in the

blast furnace. It is believed that by an alteration in the form of furnace, this will be no longer an exception. Among the uses which have been proposed for natural gas, is the manufacture of electric-light carbons, and the conversion of iron into steel. Mr. Metcalf also mentions another very important application of natural gas, which, if successful, and it seems likely to be completely so, will work a great change in that branch of work. He says: "All who are familiar with the manufacture of very thin sheets of metal, either iron or steel, know the great difficulty there is in pickling the scale off in order to get a fine finished surface. They know the danger of the acid penetrating through the metal and destroying it. It is a difficult thing to do well, and the operation is one that must be done carefully, and is one that any one who has it to do will be glad to get rid of. The process, for which an application for a patent has been made, consists in annealing fine sheets by bringing the annealing box up to the required heat by the use of the natural gas, and then by a pipe connected into the box, when the metal is hot enough, turning in a stream of the natural gas on to the material and allowing it to pass through, keeping the box hot for some little time, and then allowing it to cool gradually, when the whole mass of sheets come out perfectly clean, as clean as tin, but not as bright, but entirely clean, and, singular to say, though the sheets are very thin and packed closely in heavy boxes, this gas in some way gets in among them all, and they come out perfectly clean and free from scale."

PERMANENCY OF SUPPLY.

The fear lest the flow of the gas from the wells should prove to be only a transient phenomenon has deterred many manufacturers from going to the expense of making the alterations necessary for its introduction. From the very nature of the case it is but reasonable to suppose that, when an opening has been made in a vein of pent-up gas, it is but a question of time how soon the pressure will be relieved and the flow cease. In the case of every well that has been opened a diminution of both the volume and force of the flow has been observed, and the tendency has been towards ultimate extinction. It was very desirable, therefore, that a careful examination of this feature of the gas supply should be made. The history of a large number of wells has been examined with reference entirely to this. The following data regarding the wells drilled by a large manufacturing establishment for the supply of its own works are of interest in this connection.

No. 1. Has been in use nine years, and is still a good well.
" 2. Four years in use, still flowing, though with diminished force. Its location is three miles from any other gas belt.
" 3. Yield insignificant.
" 4. Pressure diminished from one and a half pounds to 0 in one week.
" 5. Failed after four years' use.
" 6. In use six years, gradually failing.
" 7. Failed after five years' use.
" 8. Good yet. Drilled in 1883.

No. 9. Dry hole.
" 10. Was a small well.
" 11. A good well. Gas struck within a few days.

These wells are all in Butler County, and the partial failure of some of them may be attributed to the close contiguity of numerous oil wells of that district by which they have been drained. The failure in other wells which have ceased to flow, or flow with largely diminished force, may be attributed, in some cases, to their being choked by deposits of salt or paraffine. These obstructions have, in some instances, been removed with entire success by the use of explosives. A number of gas wells are now in full blast, having apparently suffered no diminution, and have so continued for twenty years or more. One in Venango has furnished both fuel and power by its own elasticity for twenty-three years, showing no diminution. The wells at New Cumberland, West Virginia, have supplied gas for more than twenty years for the manufacture of brick. The East Liverpool wells have been burning twenty-five years, and are still productive. The gas wells at Fredonia, New York, which have already been alluded to, have been pouring forth a continuous stream for sixty years. In Beaver County, at the mouth of Raccoon Creek, three miles below Philipsburg, there is a manufactory of salt. The brine is evaporated and the engine worked by the fuel supplied from the gas issuing from the same well that supplies the salt water. This has continued for twenty-three years, and there does not appear to be any diminution in the supply of either brine or gas. We have no right,

perhaps, to expect a continuance of the "roarers," or "gushers," as they are termed, but from the facility with which the gas is reached in a large stretch of territory we may reasonably expect a continuance of supply. It may be necessary, perhaps, to arrange for the storage in capacious gasometers of the supply coming from a number of smaller wells and for its distribution from these. It is the opinion of those who have devoted considerable attention to this that with proper care in its collection and distribution the supply of gas to Pittsburgh for manufacturing purposes is an assured thing. The large investment of capital is the best evidence that we can adduce of the faith that is placed in it. The number of companies chartered to supply natural gas in Pennsylvania up to February 5, 1885, was 150, representing a capital stock of $2,160,580. Since that date a large number of new charters have been granted.[1]

The subject of the enormous waste of this valuable material has attracted much attention, and, in all probability, stringent laws will be enacted regulating the opening of new wells, and for the prevention of this waste. It is stated upon good authority that more gas is being wasted within twenty-two miles of Pittsburgh than is being used. It has been estimated that 65,000,000 to 70,000,000 cubic feet of gas are going to waste daily in the Murraysville district alone.

[1] Report of Engineers' Society of Western Pennsylvania.

NATURAL GAS AS AN ILLUMINATOR.

The chemical analysis of the natural gas coming from different localities, although varying considerably, shows that the deficiency in the carbon element renders it vastly inferior in luminiferous properties to gas manufactured from coal. It really possesses only about one-half of the lighting power of average coal gas. For all other domestic purposes, besides this, it is admirably adapted. The complete avoidance of dust, ashes, and coal carriage is gratefully welcomed in a city where smoke, smoked ceilings, smoked walls, dingy paint, rendered so by the soot and sulphurous fumes, were on every side the rule. Attempts have been made to remedy the deficiency in illuminating power by supplying to the natural gas, carbon, in some form. It has been suggested to mingle with it some of the heavier hydro-carbon vapors, but we are informed that these experiments have not as yet proved successful, as these heavier hydro-carbons are prone to separate in layers at the lower part of the gasometers. Considerable attention has also been given to the alteration and improvement of burners. Experiments are in the right direction here, and when the low price of the gas is taken into consideration it may be quite possible to obtain the same amount of light from gas having one-half the illuminating power by burning twice the number of cubic feet.

Explosibility.—A number of accidents have occurred, some of them of a serious character, resulting from the explosive nature of this well-gas, which has caused many persons to view its introduction into general use with grave

apprehension. That natural gas will explode under certain conditions, and when mixed with proper proportions of atmospheric air, is certain. It would be of no value at all if it did not have that property. Gas made from coal containing more free hydrogen, ignites at a lower temperature even than well-gas. In a mixture of atmospheric air and gas, a smaller proportion of well- than of coal-gas makes an explosive mixture; in one case $\frac{1}{10}$, in the other $\frac{1}{6}$. The danger, however, from the use of well-gas is enhanced considerably from the fact, that it is inodorous (or nearly so); while coal-gas is offensive and its presence, even in very small quantity, is instantly detected. It has been proposed to obviate or lessen the danger by the admixture of some odorous vapors by which its presence in a room might be instantly detected. The following table is taken from the report of the Western Engineers' Society already mentioned:—

Table showing comparative Inflammability of Natural Gas and Coal Gas.

Mixture of natural gas and air.		Effects.	Mixture of Allegheny City coal gas and air.		Effects.
Gas.	Air.		Gas.	Air.	
1 volume.	4 volumes.	Burns feebly.	1 volume.	4 volumes.	Burns feebly.
1 "	6 "	Burns slowly.	1 "	6 "	*Explodes.*
1 "	9 "	Burns slowly.	1 "	7 "	Burns explosively.
1 "	8 "	Burns rapidly.	1 "	8 "	" "
1 "	9 "	Burns explosively.	1 "	9 "	" "
1 "	10 "	*Explodes.*	1 "	10 "	Burns explosively, less rapid.
1 "	12 "	Burns somewhat explosively.	1 "	12 "	Flashes.
1 "	13½ "	Burns quietly.	1 "	13½ "	No flash.
1 "	15 "	Flashes, but flame dies out.	1 "	15 "	"
1 "	16 "	Very feeble flash.	1 "	16 "	"

That accidents should have occurred through haste, inexperience, and, perhaps, the negligence of those engaged in laying pipes to conduct the gas, is not to be wondered at; such work should be done under strict municipal surveillance and regulations. Whatever may be said respecting the right, under existing laws of natural-gas companies to place their pipes in the city streets, such right surely cannot debar any city or corporate community from enacting the strictest regulations to insure the safety of its citizens.

Natural Gas at Pittsburgh.

The city of Pittsburgh, Pa., is, at the present time, the theatre of some very extensive experiments in the use of this natural gas as a fuel in nearly all the various manufactures of iron, steel, glass, and chemical products. This city appears to have the advantage of being able to tap three or four prolific gas belts or fields. Mr. William Metcalf, C. E., of this city, says: "An observer standing on a hill-top in Allegheny Township, Westmoreland County, say about three miles southeast of the confluence of the Allegheny and Kiskiminetas Rivers, can see on a dark night on the northwestern horizon the reflection of the lights from the Butler County wells; to the north the lights from the wells in the direction of Kittanning; to the northeast the Leechburg and Apollo wells; to the southeast the Murraysville wells, and to the southwest the lights of the Tarentum wells. Off in Washington County and

down towards Steubenville, there are other wells, while at Hulton, in Pittsburgh, in the east end, at Soho, at Brownstown, at Sligo, and in Bayardstown, there are wells upon wells, "roarers" and "gushers." These wells are all on the same straight forty-five degree line, northeast and southwest. Some of these wells give out their gas at an enormous pressure. A gauge on a six-inch pipe situated some miles from the wells, registered, November 18, 1884, 120 pounds to the square inch, and the noise of the rushing gas indicated that the gauge was about right."

Professor J. Lawrence Smith describes graphically two prolific wells known under the names of "the Burns" and the "Delameter." These are separated by at least half a mile, and are located in Butler County, seven miles northeast of Butler and about fifteen miles from the Harvey wells, of which the gas is conducted to Pittsburgh. The two wells are located about thirty miles, measured in a straight line, from Pittsburgh. Their depth is about 1600 feet down to the fourth sand stratum so well known, at least by name, to those engaged in petroleum production. The Burns well it is believed has never yielded oil, but the Delameter, first carried to the third sand layer, was a petroleum well at 1600 feet; sunk afterwards to the fourth stratum, it gave gas at such a pressure that the tools of about 1760 pounds weight might be withdrawn by hand. Each well is $5\frac{5}{8}$ inches in diameter.

The Delameter well is the more remarkable. It produces nearly double the quantity of gas of the Burns, and furnishes light and fuel to the entire neighborhood, includ-

ing the village of Saint Joe. It is situated in a valley surrounded by high mountains, which reflect and concentrate the light of the ignited gas. Many conduits start from the well: one leads the gas directly to the cylinder of a powerful motor, which, by its pressure alone, acquires a prodigious velocity, and if the gas at the exhaust of this be lit, an immense flame is produced. Another pipe feeds a second flame capable of reducing as much iron ore as half the furnaces in Pittsburgh. At 64 feet distant is the principal escape orifice of the well. From a tube 3 inches in diameter, a column of fire 40 feet high shoots forth with a roar that fairly makes the hills tremble. Over a radius of 50 feet around the earth is scorched, but farther away the vegetation is abundant and as vigorous as in the tropics, and appears to enjoy a perpetual summer. During a calm night, the noise can be heard at a distance of 15 miles. At 4 miles, the sound resembles that of a railroad train crossing a bridge near at hand, and, finally, as the escape orifice itself is reached, the roar is like that of a thousand locomotives blowing off steam together. At the distance of an eighth of a mile, the sound is like a cannonade. The human voice is hardly able to make itself heard, and the flame seems to leap into the air, at times, to the height of 70 feet, resembling a burning steeple. In winter, even when the hills are covered with snow, for fully ten acres about the flame the grass is green and flourishing. Its illuminating power is $7\frac{1}{2}$ candles, coal gas being nearly 16. At the well, in a tube of $5\frac{5}{8}$ inches, the pressure is about 100 pounds per square inch, and in a tube of 2 inches, in which

the gas is led to Freeport, 15 miles from the well, the pressure is 125 pounds.

The ascending velocity is in round numbers 1700 feet per second, and if this be multiplied by the area of the tube 24.7 square inches, a yield of 289 cubic feet per second, or 17,340 cubic feet per minute, or about one million cubic feet per hour is determined. The quantity of gas furnished daily is thus 1408 tons. Taking into consideration that for the use of furnaces, the combustion is much more complete than that of bituminous coal, and that the effective heat produced is 25 per cent. greater, the yield of the well in combustible material is estimated at about four million pounds daily.

For more than fifty years Pittsburgh has been called the Smoky City. The extensive and apparently inexhaustible beds of coal and iron in the immediate vicinity, have attracted large capital, to be invested either in the manufacture of iron, the production of coal, or in some of the varied forms of industry dependent upon, or associated with, these interests. Hundreds of tall chimneys belched forth continually huge volumes of black sulphurous smoke, tinging every building with its sooty hue. Although the introduction of the natural gas is quite recent, the change wrought in this respect through its instrumentality is remarkable. A recent letter informs us that within a single year, great strides have been taken here in the natural gas industry. In this city alone not less than $6,000,000 are invested in practically applying the gas; add to this its introduction as fuel in surrounding towns and the

villages of adjoining counties, and it will make an additional $4,000,000, or a grand total of $10,000,000 invested in an industry in Western Pennsylvania that was practically unknown a few years ago. This sum embraces the cost of boring wells, labor, and machinery requisite for the work; purchase of lands on which the wells are located; purchase of right of way for pipe lines; increase of machinery of pipe-mills for the manufacture of thousands of tons of pipes; the cost of these iron pipes, freight bills on the delivery of pipes, the wages of thousands of laborers in laying pipe lines; plumbing and pipe-fitting in mills, factories, and dwellings; changes necessary for the adaptation of furnaces and stores for the use of natural gas; and the manufacture of gas-fittings, gauges, and meters. A year ago the subject was insignificant; to-day it ranks in importance with the iron, steel, glass, and coal interests of Western Pennsylvania. Each and every one of them has become dependent on the resources of the new fuel.

Notwithstanding that its introduction is so recent, it is estimated that the daily consumption in this city alone of this gas, as fuel, is from 15,000,000 to 20,000,000 cubic feet. For heating purposes it appears inevitable that it will supersede all other kinds of fuel. There are at present ten iron and steel mills in this city using it in their puddling furnaces and under their boilers. A dozen more are busy making arrangements for its introduction, and almost every manufacturing firm using steam is awaiting the completion of the necessary pipe lines. Six glass factories in this city, and seven others in the immediate vicinity, are using it.

Every brewery in the city uses it instead of coal. Two of the largest hotels use it for cooking purposes entirely. For general household purposes, on account of its cheapness, its cleanliness, and convenience of application, it has no rival. The same letter states that at the present time the Consolidated Fuel Gas and Penn Fuel Companies are the only ones delivering gas in the cities of Pittsburgh and Allegheny. They have in operation four lines of pipes from their wells at Murraysville to Pittsburgh, a distance of twenty miles, delivering into the gas holders here about 10,000,000 cubic feet per day; another line of 10 inches in diameter is being added, which will increase the flow to between 15,000,000 and 17,000,000 cubic feet per day. The Washington Gas Company has a pipe line twenty miles in length from the famous McGuigan well in Washington County to Pittsburgh. To this they are building an additional 8-inch pipeline which will give them a capacity of 5,000,000 cubic feet per day. The Philadelphia Company is busily constructing three gigantic lines, one from Murraysville, another from Tarentum, and the third from the famous Westinghouse wells at Homewood within the city limits. These lines will have a combined capacity of about 30,000,000 cubic feet per day. The Carpenter Company is arranging to deliver 4,000,000 and the Chambers Company 3,000,000 feet per day. Already three iron mills have gas wells at their doors, and other firms are boring private wells. A gentleman connected with the Edgar Thompson Steel Works, Pittsburgh, states: "We have an 8-inch pipe through which we get the gas for making the steam for

40,000 horse-power every twenty-four hours and do heating for 600 tons of rails; *in other words, the 8-inch pipe will represent 400 tons of coal every twenty-four hours.* One large plate-glass company on the Allegheny River estimate their saving in fuel at about $1000 per day. In other branches of manufactures the saving is in the same proportion. A statement from the daily press is made in reference to Pittsburgh affairs, dated June 22, 1885, that: "By the first of July every iron and steel mill in Pittsburgh and vicinity, with one exception, will be using natural gas as a fuel. This will reduce the consumption of coal here 38,250,000 bushels per annum, or one-seventh of the yearly output of the region tributary to Pittsburgh. It will also throw out of employment thousands of firemen, coal-heavers, and ash-haulers employed in the mills." The calculation is based upon the estimate of an output of 750,000 tons of finished iron and steel, and that it takes about 50 bushels of coal to make one ton of iron.

"The Neff Petroleum Company," which, under the management of Peter Neff, of Gambier, Ohio, made the recent explorations for oil, has lately been reorganized under the name of "Kokosing Oil Company" and has attempted to utilize the gas in a novel manner which gives promise of complete success. It has expended about $25,000 in erecting buildings and appliances for the manufacture of carbon-black, and is now obtaining a product not excelled by anything in the market. The well has a capacity of producing about 500 pounds per day, said to command at wholesale 80 cents per pound. The fact that the gas has

flowed from the well without diminution for ten years gives good promise of its permanency.

An oil well was bored in 1867 in Vinton Township, Vinton County, Ohio; at the depth of 95 feet, a seam of coal was reported measuring 5 feet in thickness. At the depth of 490 feet a fissure containing gas was struck. The gas rushed up with great force and took fire from the boiler furnace 40 feet distant, and burned to a height variously estimated from 75 to 200 feet. The burning continued for a fortnight, and caused no little consternation among the people of the neighborhood. The gas is still emitted with great force. It seems a great pity that so much heating and illuminating power should go to waste. In many places this gas would be worth thousands of dollars each year. There is apparently little diminution of the volume of the gas from year to year. This fact and similar ones indicate the probability that there are large areas throughout the State where wells might be profitably bored for gas.

CHAPTER IX.

TECHNOLOGY OF PETROLEUM.

THIS branch of our subject necessarily embraces several distinct topics; considered as a whole, it relates to the treatment of crude petroleum in any of its various forms, to fit it for use as an illuminant, as a lubricant, or for any of the multiform purposes for which it is employed. The amount of the crude article used in its natural state bears a very small proportion to the quantity employed after it has undergone some process of purification and chemical treatment. We have already stated that, in a few rare instances, this oil has been extracted from the earth so limpid, so transparent, and so nearly devoid of color and odor, as to burn readily, affording an excellent light without any treatment whatever. There have also been found oils of a heavier gravity, so entirely divested of the lighter ingredients and so free from paraffine as to stand a low degree of cold test, and to form, without any previous treatment, most excellent natural lubricating oils, commanding a high price and a ready sale, but the proportion of such oil of either kind is very small. Nearly all require some modification of their gravity or odor or fire-test to fit them for use. The methods employed to effect these necessary changes will be discussed under the heading we have selected for

this chapter. The subject naturally divides itself into two heads. We will speak first of oils, which are subjected to distillation; and secondly of those which are manipulated without undergoing this process. These two divisions admit of, and will be discussed under, several subdivisions. Under the first division we will treat of those methods usually employed in preparing illuminating oils and the purification of the lighter products, such as benzene and gasolene. Under the second will be disposed of the lubricating oils, their mode of preparation and rules for their combination. While these two classes of oils are quite distinct in their use, it will be found that in describing the process of manufacture of one variety, we will be entering into the domain of the other.

The distillation of mineral oil for the purposes of illumination is by no means so recent an art as many suppose. As early as 1694 patents were obtained in England for making "pitch, tar, and oyle out of a kind of stone." Upon a much more extensive scale in 1781 the Earl of Dundonald obtained oils from coals by the same process. Mansfield's patent, granted 1847, for "the improvement in the manufacture and purification of spirituous substances and oils applicable to the purposes of artificial light," formed the most important contribution to discoveries in this line which had been made for many years. During the same year, Mr. James Young commenced his investigation and experiments upon the distillation of a substance which has been called "petroleum peat." In 1850 Mr. Young and the geologist, E. W. Binney, made the discovery of a highly

bituminous coal at Boghead, in Scotland. Works for the manufacture of oil by the process of distillation of this variety of coal were established and conducted on an extensive scale for about fifteen years. In 1856 patents in this country were taken out and a number of refineries were built, a royalty paid upon the manufactured product, the coal being brought from Scotland. Upon the discovery that oil of equal quality could be produced from Breckenridge and other coals, the American refiners refused any longer to pay a royalty. Expensive lawsuits followed this refusal, resulting in the defeat of the patentee, and no further royalties were paid. The business of the manufacture of the shale oils had assumed large proportions, and heavy investments of capital had been made, when it was discovered that the owners of these establishments had entered into competition with a rival whose resources were unlimited. The oil was already formed in the bowels of the earth, and these vast reservoirs had only to be tapped to pour forth inexhaustible supplies at a merely nominal price. The discomfiture of the "coal-oil refineries" was complete and almost as sudden. Many large capitalists were hopelessly wrecked. A few were able to adapt their buildings and a small proportion of their machinery and apparatus to the changed condition of affairs, and began to refine oil rather than to manufacture it.

The stills employed in the manufacture of oils from coal were usually made of cast-iron. The castings were in three sections, the egg-shaped bottom, the cylindrical central portion, and the dome-shaped top piece. These three

portions were fitted together by flanges and iron screw bolts. The upper dome was fitted with a man-hole and a cast-iron goose-neck, which formed the connecting link between the still and the condensing apparatus, which consisted either of a coil of copper pipe surrounded by water in a tank, or of straight cast-iron pipe in convenient lengths bolted together. These stills were set in brickwork with large fire surface, the brickwork inclosing the whole body of the still. They rarely exceeded one thousand gallons in capacity. Notwithstanding the heavy pecuniary loss sustained by the early coal-oil manufacturers in the suspension of their branch of business much valuable experience had been acquired in the handling of hydro-carbon products, and gave to those who promptly accepted the changed position of affairs, and adapted themselves to it, an immense advantage over others who went into the business of refining petroleum without any previous training.

Location of a Petroleum Refinery.

The choice of a suitable place for an establishment of this kind is of prime importance. A mistake in this matter will probably be fatal. The close competition will not allow anything short of minimum charges in the way of transportation of the crude material or any deficiency in the convenience of placing the refined product directly in the hands of consumers; whether this be intended for export or for the home trade. If the oil is intended for export, it is

manifest that the refinery should be so situated that sea-going vessels of large tonnage may receive their cargoes at the wharves immediately adjacent to the works. It is also of great importance that they be located with reference to railroad facilities, whether the crude oil be received through pipe-line or not, for the reception of supplies of coal, oil of vitriol, etc. The largest works now in operation in this country are at Hunter's Point and Newtown Creek, Long Island; Bayonne, New Jersey; Point Breeze, at the junction of the Delaware and Schuylkill Rivers, Philadelphia; at Thurlow, on the Delaware River a few miles below Chester, and near Baltimore, Maryland. Perhaps the most extensive and best equipped of these are located at Bayonne, where the Standard Oil Company have very extensive piers of their own, and facilities for loading the largest vessels and handling six or seven thousand barrels of refined oil daily. Formerly, the largest refineries were situated in the oil region, or at least upon the line of the railroads issuing from that section. They were usually built upon the sides of hills; the storage tanks being placed upon the highest points, so as to admit of the crude oil flowing by gravity into the stills. A few establishments of very large size were thus placed on the banks of the Allegheny River, a few miles outside of Pittsburgh. The supply of the crude material was brought to them by the Allegheny Valley Railroad, switches from which road entered the works, both furnishing the crude and receiving the refined product. The establishment of the pipe-lines and the growth of the export trade have entirely changed the condition of affairs,

which at one time in the history of the oil business made such locations highly advantageous. The refineries first above named have, besides the facilities of shipment, the advantage of being in close proximity to large manufactories of oil of vitriol and chemical fertilizers, which purchase and utilize in the manufacture of super-phosphate of lime the immense quantities of refuse acid daily discharged from them.

Division of the Work.

There are but few refineries which have the facilities or the appliances for handling and putting into the market all the varieties of refined petroleum. There are manufacturers of lubricating oils who confine themselves exclusively to this class of products, and there are makers of illuminating oils who refine these only. There are also refiners of the light products of petroleum who devote themselves exclusively to this branch of the business. There are also manufacturers of paraffine wax. The manufacture of vaseline, petroline, or cosmoline, is also another branch. What is "residuum" to the refiner of illuminating oils becomes "crude material" to the manufacturer of lubricating oils. What is a "bye product," such as benzene, and sold as such by the maker of illuminating oils, becomes "raw material" to the gasolene manufacturer. There are a number of manufacturers who combine several of these specialties. This division of the work necessitates a separate consideration of each branch of the subject.

REFINING BUILDINGS.

In the early days of this industry large sums were expended in the construction of, what were intended to be, fire-proof structures. The iron stills were covered with brick or stone buildings. The receiving tanks were similarly protected. When fire came, however, which always occurred sooner or later, walls appeared to offer no effective barrier to the progress of the devouring element, and soon toppled to the ground. Costly experience has led to a far less expensive style of construction, and which is also freer from danger of such wholesale destruction. Thus while fires in these establishments are by no means done away with, they are far less frequent, and never result in their complete destruction. It is now customary to place the stills, from which nearly all the danger is apprehended, at a considerable distance from any other structure. These are now wholly uncovered. The distillates coming from these are received in a small one-story building of either brick or iron, simply for the protection of the head refiner from the elements; this building is also located at a safe distance from the still. The light which is necessary for him during the night time to observe the "runnings" of the stills is supplied to him either by an electric light or by a reflector placed outside of the structure. A very complete and convenient arrangement for the reception and distribution of the distillates employed at the Chester Oil Works at Thurlow, near Philadelphia, is represented in Fig. 24. The receiving tanks are now almost universally

placed under ground and covered with soil. The condensing tanks are wholly uncovered. The "agitator" mostly built of iron, and resting upon brick or stone piers, has no other covering than a light iron roofing fitted with trap

Fig. 24.

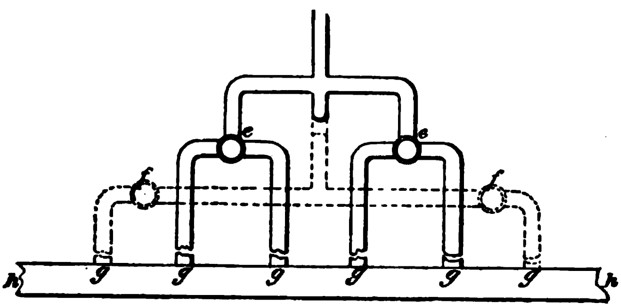


Diagram showing Arrangement for Distributing Distillates.

doors which serves the purpose of preventing rain from entering the tank. The boilers, which supply the establishment with steam, have usually a brick, stone, or sheet-iron building, affording by this means a saving in fuel and protection to the coal. The settling tanks are simply covered with a board roof, and the warehouses and barrelling house, which are connected with the settling tanks by means of an underground pipe, are at a considerable distance from the other structures, and if possible at the wharf for convenience in loading vessels with the refined product. The "office," especially in some of the larger establishments, is more pretentious, but the works themselves, even of the largest, are as much exposed to the elements as the rudest concerns in the oil regions.

In estimating for the construction of a petroleum

refinery, the first subject to be considered is the number of barrels of crude oil per day it is proposed to handle, every item of the calculation in the construction of the stills, the size of the condensing tank, the size of the boilers, the capacity of the receiving tanks, and that of the agitator, depend upon the number of barrels of crude oil to be operated upon daily.

Receiving Crude Oil.

Formerly this was exclusively in barrels, which were rolled from the cars upon a skid placed upon the receiving tank, buried in the ground; the bungs being knocked out, the contents were allowed to flow through a sieve, or wire screen, into the tank. No oil is now received in this way, except it may be in sample lots, and for some special purpose. Iron tank-cars, each holding about 100 barrels, are run on the track alongside of the works; a pipe commensurate with its capacity runs parallel with the track; it is fitted with a number of openings at distances from each other, equal to the length of the tank-cars. These are each provided with a vent underneath, to which is fitted a flexible pipe and stop-cock, and when all the connections are thus made between the cars and the underground pipe, the stop-cocks are opened, the oil flows into the pipe, the steam pump is set to work, and in a very short time the contents of a train of cars are placed in the storage tanks. These are built of boiler-iron, and frequently contain from thirty to forty thousand barrels of oil. The large refineries

near New York and at Point Breeze (Philadelphia), Pittsburgh, and Cleveland, and a few other places, are connected with the pipe-line service. The oil is received by these through the pipe-line directly into the storage tanks. In some instances the oil is conveyed a part of the distance from the wells through pipes, and delivered at this terminus into distributing tanks, from which it is placed in tank cars and conveyed in these to its destination. Formerly, the contents of the tanks or cars were determined by the actual measurement in cubical inches, regardless of temperature; but as it has been well ascertained, that oil is subject to the same changes of volume according to the temperature that other liquids are, the measurements of oil are now made to conform to the same law, and hence extensive and most comprehensive tables have been formulated to assist in the ready computation of the contents of any vessel designed to contain it.

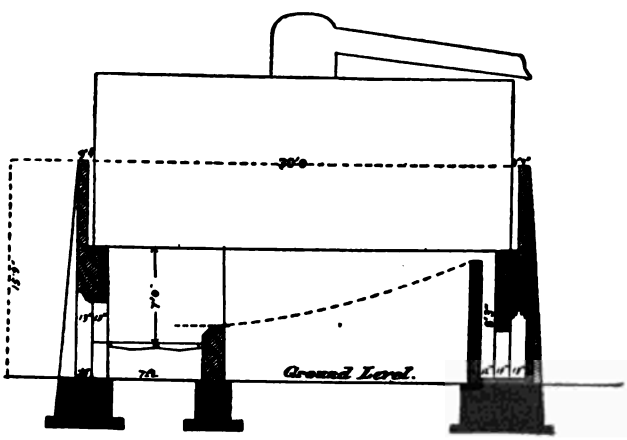
THE STILLS.

The two forms of stills, now almost universally used in this country, are known, respectively, as "the cheese-box" and "the cylinder still." The controversy as to the superiority of one or the other of these two forms still goes on. Advantages are claimed for each. The cylinder still is, perhaps, the more economical of fuel, and is more easily kept in repair: while the advantages claimed for the cheese-box over the cylinder still are lighter gravity, better color of distillates, and a larger yield of illuminating oil. The ex-

cessive cost of repairs on the brickwork and bottoms are strong inducements to the refiner to adopt stills of the cylinder pattern, and the former are being torn down and replaced by the latter. Cylinder stills rarely exceed a capacity of six hundred barrels, while some cheese-box stills have been built to contain thirty-five hundred barrels.

The Cylinder Still.—Diagrams of the cylinder still are represented in Figs. 25 and 26. They are frequently set in banks of two or more, there being considerable economy in

Fig. 25.

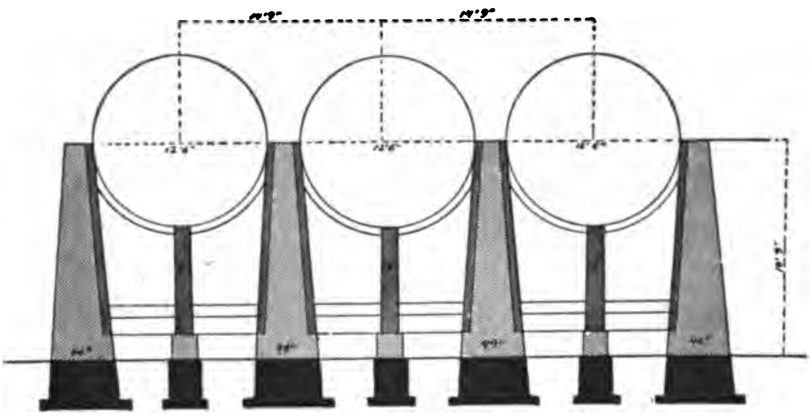


Longitudinal-vertical Section of Cylinder Still.

thus placing them. From the dimensions here given, a contractor would be able to place them without difficulty. They are 12 feet 6 inches in diameter and 30 feet in length. The capacity of this still is 600 barrels. A drum-shaped dome is usually placed in the centre of the top of the still, from which proceeds a fifteen-inch wrought-iron pipe, con-

necting it with the condensing apparatus, to be spoken of further on. It will be noticed that the brick-work only extends to the centre line of the still, the upper half being left wholly uncovered, or covered with a sheathing of thin

Fig. 26.



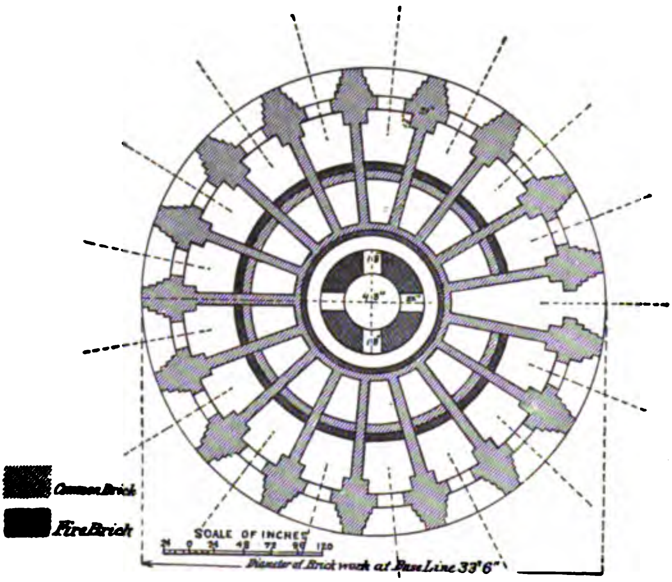
Transverse-vertical Section of Cylinder Still.

sheet iron. This arrangement of the brickwork admits of the modern method of distillation being carried on, in which the process of "cracking" is an important feature.

THE CHEESE-BOX STILL.

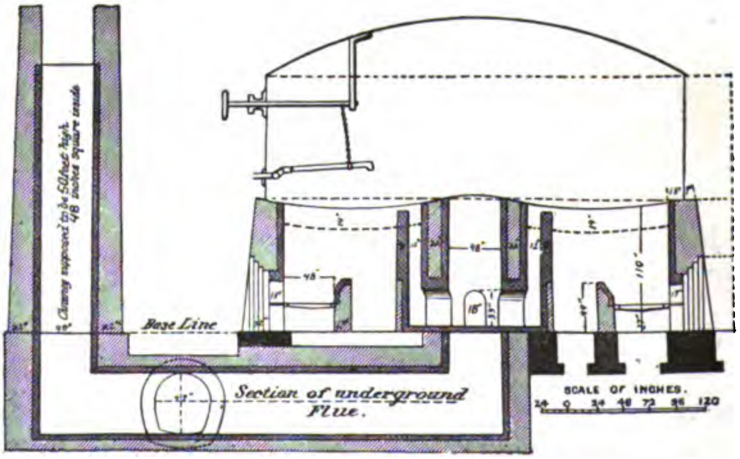
Diagrams of this form of still are shown by Figs. 27 and 28: it is 30 feet in diameter and 10 feet in height. It is supported by circular brick-work in which are built 17 fireplaces, all communicating with a central flue. The bottom has a double curvature. The discharge pipe of the still enters on the side; on the inside is a swing-joint suspended by a chain wound around a shaft which is operated

Fig. 27.



Horizontal Section of Cheese-box Still-setting.

Fig. 28.



Vertical Section of Cheese-box Still-setting.

from the outside of the still; by revolving the shaft the pipe can be either raised or lowered to the bottom of the still. From the top of this still project three pipes, each connecting with a drum stretching across the whole diameter of the still. From this drum proceed 40 3-inch pipes leading into the condensing tanks. In some stills of both patterns, at the point where the vapors pass into the drums, a perforated steam-pipe is placed. This is only employed during the "cracking" process, and is thought to greatly improve the quality of the oils both in respect to color and gravity, although the arrangement is not to be found in many refineries.

Both forms of these stills are provided with man-holes, for the double purpose of allowing the workmen to enter and clean them, and occasionally to inspect their condition. One is placed upon the top of the still, a second near the bottom plate which allows the refuse coke to be conveniently thrown out. The covers to these are generally fastened in their places by means of screw bolts and nuts. Many of the most expert and careful refiners use pyrometers in their stills; they are often of great assistance both to the fireman and the distiller. The large-sized stills are built of the very best quality of boiler-iron, of $\frac{3}{8}$ or $\frac{5}{16}$ inch thickness, securely caulked. The bottoms are of steel of the same thickness. The increased expense in the use of steel for the bottoms is more than compensated for by their enhanced durability and safety.

Both forms of stills are usually provided with steam-pipes both closed and perforated. The steam issuing in jets from

the perforated pipe has been found to facilitate distillation by carrying over mechanically the oil vapors.

VACUUM STILLS.

It was very early noticed that the intense heat necessary to volatilize the heavier portions of the hydro-carbon oils had an injurious effect both on the color and odor of the distillate. Efforts were therefore made in the direction of accomplishing the distillation with the least possible heat. Water under the ordinary pressure of the atmosphere boils at the temperature of 212° F. It is known that under a reduced pressure this temperature of boiling is also reduced, and proportionately. It had also been observed in the manufacture of sugar, in the evaporation of the syrupy liquid, that the long-continued heating seriously affected the crystallizing properties of the syrup, thus reducing the quantity of crystallized product. The evaporating pans were afterwards fitted with close covers having an exit pipe, to which was adjusted a vacuum pump and condensing apparatus. It was found that under the reduced pressure the liquid boiled freely at a temperature of 120°, and the evaporation was effected in about one-fifth of the time required under the old system, besides giving a much larger yield of crystallized sugar. These views suggested the employment of vacuum stills in the manufacture of oils. Notwithstanding the apparent plausiblility of the principles suggested, the writer knows of only one establishment in the United States which has successfully introduced it,

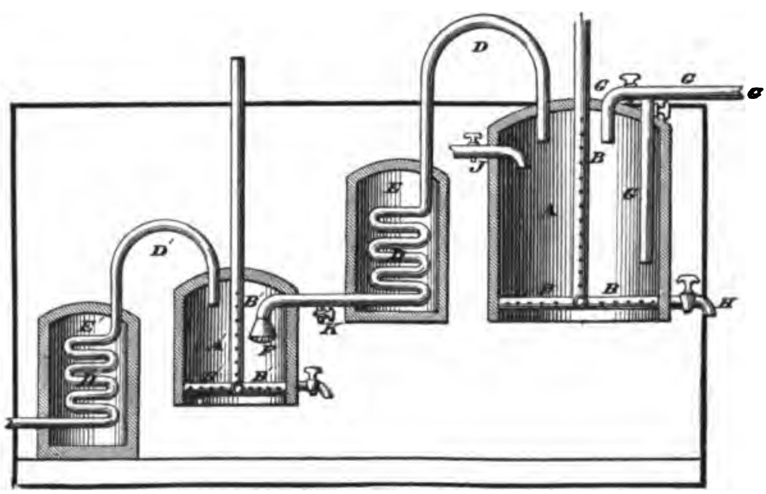
namely, the Vacuum Oil Company of Rochester, New York, which claims a superiority for its manufactured products on account of the low temperature employed in the process of distillation. It is claimed that by this mode a purely fractional distillation is obtained without a *decomposition* and ultimate deterioration of the distillate.

Continuous Distillation.

Frequent attempts have been made to introduce into the manufacture of refined petroleum the principle of continuous distillation, by which is meant a continuous flow into one portion of the apparatus of a supply of the crude oil, and a similar discharge from another portion of refined distillate. It may be remarked of this, as was said of distillation *in vacuo*, that, however plausible in theory the idea may be, in practice it has not proved its value by its general adoption. A great saving of labor and time was predicted and claimed for this method of refining oil. Numerous patents have been obtained on forms of stills constructed on this principle. Samuel Van Sycles, of Titusville, Pa., whose patent bears date May 22, 1877, suggested "a series of stills in which the oil is maintained at a constant level by means of a tank, in which a float on the surface of the oil as it rises or falls automatically controls the flow of oil." An apparatus constructed upon this principle of continuous distillation was put in operation in Buffalo, and the products actually placed on the market. I am not able to state whether any other refiners have introduced this

form of still, or whether this one continues to be operated. The annexed diagram represents a still constructed upon the same principle, designed by James Cole, Jr., of Cleveland, Ohio. The following description of its mode of operation is sufficiently explicit:—

Fig. 29.



The still *A* being charged with the liquid, such as petroleum or any one of its distillates, or the residual product left after a partial distillation of petroleum, steam is passed through the pipes *B B′*, which we will suppose to be perforated, as shown. As the liquid warms, the lighter and more volatile products will be volatilized and passed over, the very lightest passing over with a very moderate heat, and, as the heat is increased, the heavier and more condensable products successively vaporize and pass over. If steam or air blast, through the pipe *G*, is employed, these

volatilized products, as soon as they separate from the liquid, are instantly caught up and carried out of the still. As these products pass forward through the pipe *D*, the heaviest of them are condensed in the condenser *E*, and fall as a liquid into the second still, while the lighter portions pass on through the pipes *D′*, etc. That which falls into the still A^1 may pass through a rose, *F*, so as to drop in form of spray through an atmosphere which has been sufficiently heated to vaporize and drive out all except the very heaviest of the liquid product, which will remain in the still A^1. The volatilized products continue on forward through the pipe *D′* and the condenser *E′* of more power than the first, and here the next heaviest grade is condensed and falls in like manner, preferably through a rose into the third still, where a still gentler heat is applied, or may be, leaving a certain grade of liquid, and passing the vaporized or lighter products still further forward, and so on. The result is that in the still A^1 a heavy oil is left suitable for illuminating and for other purposes, where the oil is required to stand a high fire-test, being entirely devoid of those very light and highly volatile and inflammable products that will vaporize when a very slight heat is applied, and may cause explosion.

In the still A^1 is a lighter oil of lower fire-test, but still devoid of the lighter and more explosive and more highly volatile products. The still A^2 contains a still lighter product, and so on, as far as the process is carried.

By carefully grading the successive degrees of heat in

the successive stills, this process may be carried to any extent desired, and the original oil may be separated into a large number of slightly different grades; or, in the same set of stills, any one of the grades that has been collected as above may be treated in like manner, and be separated into separate and distinct grades.

By faucet *H* the products remaining in the several stills may be drawn off as collected, and, by a feed-pipe, *J*, the still *A* may be supplied with fresh liquid as rapidly as distilled, and thus the process may be made continuous, and all the different grades may be produced and collected simultaneously, and by a single operation.

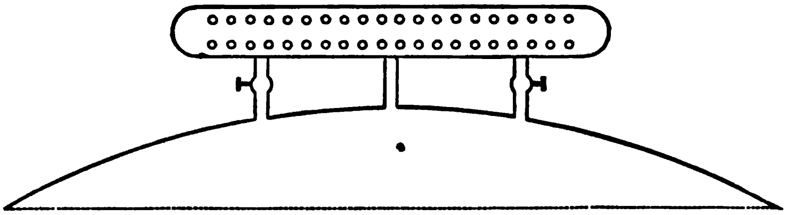
Faucets *K* may be located at suitable points for drawing-off and testing the products at any point.

Condensing Apparatus.

It would quite exceed the limits, or the design, of this work to describe minutely the variety of forms of the condensers used in this connection. The old-fashioned cast-iron goose-neck is seldom seen, having been supplanted by the large wrought-iron pipe, or by the arrangement previously described and represented in Fig. 30, or by the insertion directly into the dome of the still of a large number (40, 50 or more) of two- or three-inch iron pipes. These sometimes form so many continuous separate coils in the condensing tank, converging near the bottom of the same into one large exit pipe, or they may only extend to the top of the tank, and there enter a large pipe perhaps

twelve inches in diameter, which gradually tapers as it approaches the bottom of the tank to one of three or four

Fig. 30.



Section of condensing drum.

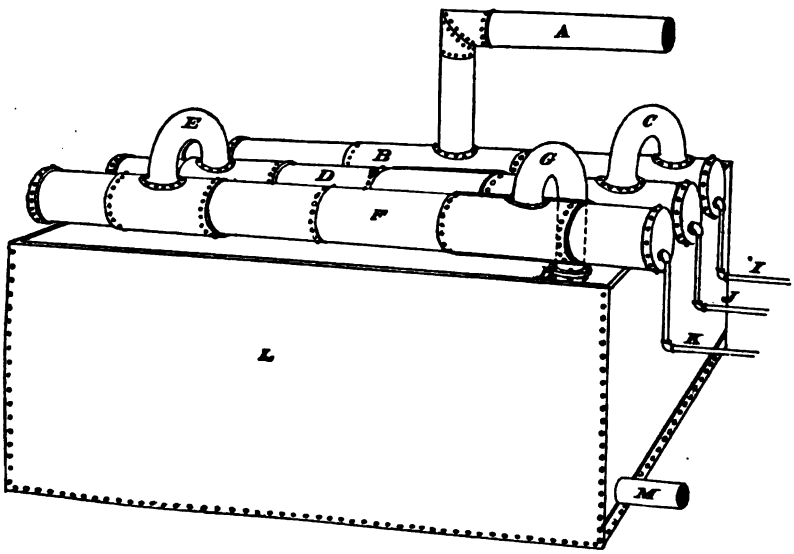
inches. Still another form of condenser in which water condensation is supplemented by an arrangement for aërial condensation, is employed. The apparatus is rigged immediately above the water tank and rests upon it. In the winter season it adds very materially to the condensing surface, besides affording an easy, rapid method of dividing the products of the distillation at one operation into at least three distinct gravities of oil or benzene.

The following diagram (Fig. 31) will illustrate this form of aërial condensation:—

A represents the large pipe leading direct from the still and connecting this with the condenser. *B*, the first air condenser, is an iron cylinder of $\frac{3}{16}$-iron, 30 feet in length, 24 inches in diameter. *C* is an elbow connection between the first and second air condenser *D*, of same dimensions as the first. *E* is an elbow connection between the second condenser *D* and the third condenser *F*. *G* is an elbow connection between the third air condenser *F*, and the

usual condensing pipe *H*, which here enters the water in the tank *L*.

Fig. 31.



Any light benzene, which admits of condensation by simple exposure to the air of the condenser *B*, passes through the pipe, *I*, into its appropriate tank. A heavier grade of benzene requiring a still greater degree of cold is subjected to this in the second cylinder and runs off through the pipe *J*. A still heavier grade of the lighter products, which will not admit of condensation, passes into the third air condenser and passes off through the pipe, *K*. Any product which requires a greater degree of cold than the air will supply passes into the regular condensing worm at *H*, and is graded subsequently at the receiving house in the usual manner. In the working of the apparatus in the earlier

part of the operation, three grades of benzene are running at the same time, and also during the "cracking" process, a portion of light product the result of the decomposition of the heavier oils may also be received through the medium of the air condensers.

Whatever form of condensing apparatus may be employed, two important features must receive due consideration. There must be no stint either in length or size of the condensing worm, or in the quantity of water supplied to the tank. The writer has observed that every addition made to the capacity of the condensing arrangement was attended with an improvement in the quality of the oil and an economy of time in employing the still. A six hundred barrel still will require at least a thousand feet of six inch tube, or its equivalent in piping of a smaller diameter.

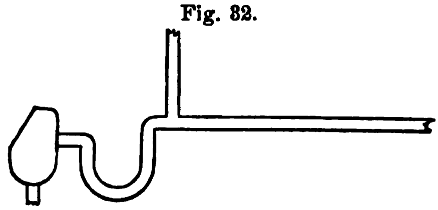
The condensing tanks are usually built of iron, generally oblong, but sometimes also circular in form, in either case resting upon solid masonry of stone or brick-work; condensing worms are also frequently formed of cast-iron pipe, four to ten inches in diameter, in lengths of 6, 8, or 10 feet, flanged and bolted together. It has been claimed that they are more economical. This is questionable, and in many respects they are vastly inferior to the usual lap-welded wrought-iron pipe.

The supply of water is not second in importance to the capacity of the condensing worm; an abundance of water is especially needful in the summer season, and under no conditions should the distillate be warmer, upon issuing from the tail pipe, than the water supplied to the condenser. A

warm distillate, if in a large body, retains its heat for a long time and rapidly darkens in color. In this condition it is violently attacked in the acid treatment, and the product will generally be found to be "off color." This result, however, can be guarded against by cooling the oil before subjecting it to the acid treatment. It will be found a wise economy in the end to invest liberally in the condensing arrangements.

The terminal portions of the condensing pipes all converge and enter the receiving house within a few inches of each other. Near the extremity of each, a trap (Fig. 32) in the pipe is made, for the purpose of carrying away the

Fig. 32.



incondensable vapor. This vapor is burned underneath the boilers or stills, effecting thereby a large saving in fuel. The location of some refineries in certain large coal-distributing centres enables their proprietors to employ large quantities of fine refuse coal or coke by mixing the same with the *cokey* settlings of the residuum. Neither of these could be employed separately as a fuel with advantage, but mixed, as before stated, they form by far the larger proportion of the fuel used. The fire, at certain stages, or when these are not combined to the best advantage, may be urged by a blast of air.

Distillation of Petroleum.

A careful perusal of the chapter on the chemistry of this substance will greatly aid one in comprehending the general principles involved in this, the first process, in refining petroleum. That this peculiar and highly complex body is composed of a series of hydro-carbon compounds, varying in gravity from an incondensable gas to a solid substance, does not appear to admit of a doubt. How this peculiar compound is constituted, or its component parts are held together, is by no means so clear, and the question first propounded by Professor Silliman after his admirable analysis, whether the different distillates obtained by him, each differing from the others, were so many distinct *products* of the destructive distillation of the oil, or whether they were *educts* of varying compounds already pre-existing in the oil, has not yet been satisfactorily answered, at least not that I am aware of. Mr. Warren, of Boston, claims to have obtained products which maintain throughout the whole distillation equable boiling points. Granting this to be the case, and his experiments were too accurate to doubt their correctness, we would assume petroleum to be a mechanical mixture of a series of hydro-carbons of a definite composition, and capable of being separated from each other by careful distillation. There is one fact which is matter of common observation among oil men, which would tend to confirm such a view of its constitution. An oil tank containing a large quantity of distilled oil, if allowed to remain undisturbed for several

months, will be found to contain several grades of oil; the upper portion being several degrees lighter than the bottom; the heavier portion obeying the ordinary laws of gravity finding its proper level. It is not necessary for us either to assent to, or to deny, the correctness of this purely mechanical view of the subject, to explain the practical methods of dividing crude oil into marketable products.

The stills having been placed in proper position, and all the connections with the condensing apparatus having been carefully inspected, they are filled to their estimated capacity. To save time the crude-oil pump, especially, should be large. A twelve hundred barrel still should be filled in thirty minutes or less. The fires being kindled, the work of emptying now devolves upon the fireman and the distiller, and the varied experience which they acquire in their respective positions is of immense value. A gentle fire is started, and the distiller, whose position confines him exclusively to the receiving house, is notified by speaking tube or signal, that still No. — is "fired up." The light products known under the generic name of benzene soon make their appearance. In this early stage of the process the diversity of methods employed by different refineries manifests itself. A certain refiner, who may have a local demand for all the light product above a certain gravity, will allow the whole of his benzene run to flow into one benzene tank, from which it is barrelled and sold. Another refiner may have a demand for two or more grades of benzene for specified purposes. With this division of the product in view, he will of course provide himself with

two or more separate tanks, and direct his light distillate into each according to gravity.

The point at which the distiller "cuts off" his benzene and directs the product into the oil tanks, varies according to the kind of oil he manufactures. For an oil of low fire-test, say 110°, some refiners cut off as high as 64° Beaumé scale; most generally, however, it is considered safer to continue "the run" down to 62°. The benzene distillate between 70° and 62° contains quite a percentage of burning oil. The "run of the still" between these two points is, by some refiners, who are bent upon extracting the largest yield of burning oil, laid aside for separate distillation, the heavier portions being separated and run into the oil. To make an oil to stand 120° fire-test, it is never safe to cut off above 62°. An oil with a fire-test of 150° and "water-white" in color, known in the trade as "head-light," is now much in demand, commanding a higher price. In the manufacture of this variety, the lighter products of distillation are kept out until the Beaumé indicates 56°. In this process a large percentage of oil between 62° and 56° is obtained, which may be returned to the benzene tank, but is generally reserved for the manufacture of the 110° oil. Having disposed of the benzene "runnings" according to the grade of oil to be made, the burning oil is then directed into its special tank. The still-man now urges his still to its utmost, being guided in his directions to his fireman very much by the color of his distillate. The saving of time is all important in this part of the operation, in order to accomplish his run in a specified

time. If his still is driven too hard, however, minute particles of crude oil may be mechanically driven into the condenser, and seriously impair the color of the distillate long before the gravity of the oil should indicate a change of color. A difficulty in this direction is quickly and easily remedied by slackening the fire and thus reducing the outflow. In this part of the operation the still-man is guided almost exclusively by the color of the distillate. After about two-thirds of the contents of the still have passed over (and in crude oils of a gravity below 43°, this point is reached before this), there is marked increase in both the gravity and the color of the distillate. At this point all the experience and skill of the distiller are needed. The fire is slackened and the speed of the outflow is greatly reduced. The "cracking" process now begins, by means of which, with careful management, an excellent quality of oil is obtained until the still is emptied, leaving therein, in ordinary cases, about eight per cent. of residuum.

The "Cracking" Process.

The history of the discovery and theory of the division of the heavier products of petroleum into a number of lighter ones is interesting and its importance cannot be over-estimated. It has largely increased the percentage of the yield of illuminating oil, thus enhancing the profit of the refiner. In a recently published volume on Petroleum Distillation, by Allen Norton Leet, I find the following account of the circumstances leading to the discovery of the "*cracking*" *process.*

"One cold afternoon in the winter of 1861–62, a sixteen barrel upright wrought-iron still in a refinery at Newark, New Jersey, was about half emptied of its contents and the distillate indicated 43° gravity with rapid tendencies toward lower figures and darker color, and the still-man intended in half an hour's time to cut off the remaining portion of the outflow into the heavy-oil tank. Having built a strong fire under the still, which supposably would keep the distillate in rapid motion for a time, the attendant locked up the refinery and went to dinner. It happened that after finishing his meal he was taken with a fit, and when he was sufficiently restored to resume work darkness had settled down upon the city. He had been away from the refinery for four hours. When he had struck a light, to his surprise and amazement, he found a small stream of oil still running into the distillate tank, quite cool, light in color and 48° in gravity. Failing to comprehend how the gravity and color could both lighten up after a large portion of the contents of the still had run off, and after a much lower gravity had been reached, and fearing something was wrong with the still, the still-man drew the fire, awaiting the coming of the proprietor. When the latter arrived a thin stream still issued from the end of the worm, and to the surprise of both the specific gravity had risen to 52°. . . . In order to study the effects of the internal operations of the still, he had a heavy glass retort constructed, and, then, by experiment discovered that after the distillation of the heart of the crude oil and when the gravity of the distillate had reached 44° with descending

gradation, by reducing the temperature of the fire, the lighter vapors of what remained in the still would be carried over." By a close observation of the motion of these vapors he discovered that a portion of the product would be condensed by the cooler upper portions of the retort, and were returned to the oil of the retort. Here they were exposed to a higher temperature than was necessary simply for volatilization and were decomposed, giving rise to an increased yield of that grade of oil sought for. The theory was tested upon a larger scale in the iron retort which was adapted for the new mode of distillation by removing the brickwork from the upper portion of the still. The experiment was a success "to the delight and profit of the manufacturer."

The important results obtained by this changed method of distillation will be readily understood by an inspection of the table of the components of petroleum as analyzed by Pelouze and Cahours. In its natural state, according to this analysis, petroleum consists of a series of these hydro-carbons belonging to the paraffine series represented by the chemical formula, C_nH_{2n+2}. Hence we would recognize a hydro-carbon containing twice as many atoms of hydrogen (with the further addition of two atoms) as it does of carbon, as belonging to this series. We will take, for example, a sample of heavy oil represented by the chemical formula $C_{13}H_{28}$, specific gravity .792, boiling at a temperature of 424° F. At a heat above its normal boiling point, when it is thrown back into the oil by condensation, it is decomposed into—

One portion of the same series of				oil represented by . .	$C_{10}H_{22}$
"	"	"	"	gas, formula	C_2H_6
And "	"	"	"	carbon, deposited as coke,	C
					$C_{13}H_{28}$

The portion of oil, $C_{10}H_{22}$, has the lighter specific gravity of .757 and a boiling point of 320°. This will be found to have the right color, and can be run into the burning oil; the gas passes off at the trap; the atom of carbon falls to the bottom of the still and is removed with the coke. With careful distillation, by this process, 80 per cent. of burning oil may be obtained. Leaving for future consideration the re-distillation of the residuum and the first light products, we will take up the—

Chemical Treatment.

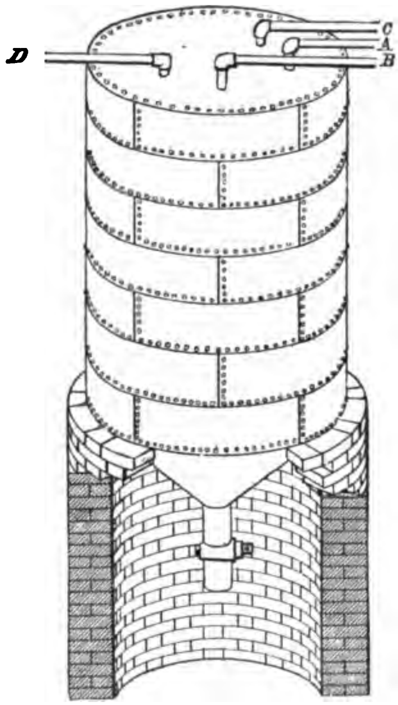
It will be found that all the distillates are permeated with a peculiar burnt odor quite foreign to the crude oil, and evidently due to the heat employed and the partial decomposition of the oil. To remove this odor and to further decolorize the distillate, it is subjected to a treatment with sulphuric acid and subsequent washings with a solution of caustic soda and water.

In order to secure a "standard-white" color in a finished oil, the distillate should have a pale-straw color. If the distillation has been too rapid, it is liable to be tinged with a greenish-hue, which the acid will not discharge.

THE AGITATOR,

represented in Fig. 33, is constructed of iron boiler-plate, lined with sheet lead. Its size is commensurate with the needs of the establishment, and ranges in capacity from

Fig. 33.



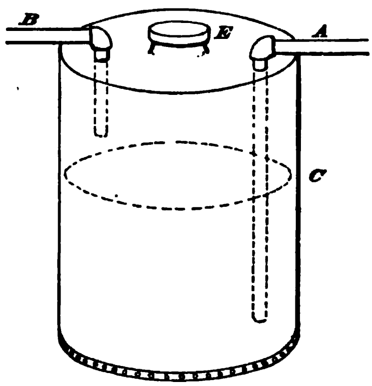
Agitator.

one hundred barrels to two thousand barrels. These agitators are generally deeper than they are wide, about in the proportion represented in the diagram. The bottom is funnel-shaped, terminating in a pipe furnished with a stop-cock for drawing off the refuse acid and soda washings.

It is supported generally on a circular brick, or stone, structure, which affords, beneath the agitator, a convenient space for the refiner to direct the agitation of the contents of the apparatus. The oil is introduced into the tank through the pipe *A*, by means of a steam pump. The temperature of the oil to undergo chemical treatment is an important feature never to be overlooked. If the distillate has passed through the condensing worm at an elevated temperature, it is not only liable to undergo spontaneously considerable change of color, but it is quite unfit to be treated, *i. e.*, if a white oil is desired. Such a distillate must be cooled, either by allowing it to stand, by placing ice in the tank, by passing chilled air through the oil, or by passing the oil through pipes covered with cold water. When the temperature of the oil has been reduced to 60° F. it is ready for treatment. The first step in the process is the careful withdrawal of any water which may have found its way into the tank. The second part of the operation is the introduction of the sulphuric acid. The acid is supplied to the works in lead-lined, air-tight tanks, from which it is transferred to reservoirs similarly constructed. In a smaller reservoir capable of containing the charge of acid necessary for one agitation, is placed the quantity needed. These transfers of the acid are made by means of a pump through the agency of compressed air. The process will be readily understood by an inspection of Fig. 34. The acid is introduced into the vessel through the opening at *E*, until it reaches the dotted line *C*, when the air-tight cover is adjusted. Air is forced in through the pipe *B*, which enters

the tank above the surface of the liquid; the pressure of air forces the acid through the pipe *A*, into the agitator. This is supplied in three successive portions. The quantity of acid required is of course modified somewhat by the

Fig. 84.



Acid tank.

color and gravity of the distillate. For the manufacture of a "standard-white" oil from a good distillate, one and one-half per cent. is sufficient. A small portion of acid is introduced at first, having previously started the air-pump and secured a thorough agitation of the oil. A few minutes' agitation is sufficient to abstract the minute quantity of water, mechanically held in suspension by the oil. This is allowed to settle to the bottom of the agitator, when it is drawn off through the stop-cock. After the air-pump is again put in motion, about one-half of the charge of acid is introduced and the real agitation commences. Immediately the chemical action of the acid upon the oil is perceived by the change of its color, and the elevation of its

temperature, which should be carefully noted by a thermometer. This agitation, with a good air-pump, is a thoroughly rigorous one, and should be continued for about forty-five minutes, or even longer in the larger-sized agitators, holding 1200 or 1500 barrels. When the temperature ceases to rise and the chemical action of the vitriol appears to be exhausted, the agitation ceases and the dark acid is allowed to subside. The time required for this subsidence is altogether determined by the size of the tank and the quantity of oil operated upon. An hour or more may be necessary. When the acid has completely settled, it is withdrawn into the "sludge acid" tank; the remaining portion of acid is then added, and a second thorough agitation for about the same length of time is given to the oil, and the process of its subsidence and withdrawal is repeated. Great care is needed that every vestige of dark acid be removed. Toward the latter part of this operation, a small portion of oil is likely to escape with the acid through the pipe. This is allowed to collect in a small tank, and is subsequently recovered.

The action of the sulphuric acid upon the oil occasions the decomposition of certain members of the hydro-carbon compounds contained in the distillate. It is claimed that if this were wholly composed of the paraffine series (C_nH_{2n+2}), there would be little or no chemical action, but the "cracking" process existed long before it was suspected or formed an essential feature of modern distillation. A certain portion of the oil always has been "cracked," giving rise to a second series of hydro-carbons (C_nH_{2n}) upon which

sulphuric acid will exert prompt chemical action. The oil and acid are both decomposed, the acid loses a portion of its oxygen, giving off dense suffocating vapors of sulphurous acid, the cast-off atom of oxygen seizes on one atom of hydrogen of the hydro-carbon oil, forming water, which goes to dilute the remainder of the acid, while the carbon atom is deposited and entangled in the acid, and is carried down with it. How far the disengaged sulphurous acid, one of the most powerful bleaching agents known, is utilized in this process of whitening the oil is not known, but it doubtless exerts considerable action.

After the last portions of the acid have been removed, the "water-washing" commences. The water is introduced into the agitator above the surface of the oil through a perforated pipe which runs around the entire circumference of the tank, and frequently through a series of pipes running across the tank. Water is forced through these pipes and through the numerous perforations into the oil, and along down the sides of the tank. As the water percolates through the body of the oil, the acid is gradually removed, and while the water is thus flowing on at the surface of the oil, it is allowed to escape in a constant stream from the bottom. This water percolation continues until as nearly as possible all traces of acid have disappeared; this operation may last from four to five hours. The stop-cock at the bottom of the agitator is now closed and a fresh portion of water added, and the air-pump again set in motion. By this means the oil is thoroughly washed. This water agitation may last for an hour or more, when this

ceases, the water washings are removed. When this is effected, a solution of caustic soda (about one per cent. of a solution of 12° Baumé) is added, when another agitation takes place, lasting perhaps thirty minutes. This refuse soda solution is withdrawn, and generally permitted to flow without any attempt to utilize it. The sludge acid is sold to the manufacturers of chemical fertilizers and superphosphate of lime. Some manufacturers close their "agitation" at this point, others give the oil a further washing with water, in order to remove any traces of caustic soda. Some purposely avoid this final washing with an idea that a trace of caustic soda has a preservative effect upon the oil. Some careful operators follow the plan, at this stage of the process, of removing a sample of the oil and subjecting it in a water-bath, to a temperature of about 212° F., to test for the presence of acid. They claim this test to be more delicate than any other, and that if there be the slightest trace of acid remaining it will manifest itself by a darkening of the oil, and the contents of the tank will receive further washing with caustic soda. After the water is drawn off the oil is allowed to flow by gravity, or is pumped into the

Settling Tanks.

These are built of boiler-iron and large enough to contain one charge from the agitator. In some of the larger refineries they are 40 feet in diameter and 10 or 12 feet deep. Before being used they are frequently given two or three coats of white paint. They are provided with a coil of hot-

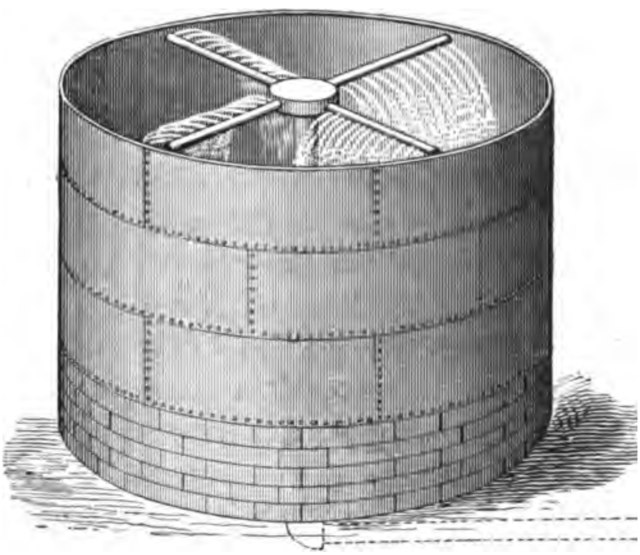
water pipe for the purpose of gently warming the oil in very cold weather. This greatly facilitates the settling of any water which may be left in it, and also its clearing. These tanks are often entirely exposed on all sides and are simply provided with a roof to keep the rain out of them. By this exposure of the oil, in a very short time, in good weather, it becomes beautifully clear and brilliant. They are also provided with a pipe connected with the steam pump which admits of the oil being transferred from one tank to another used for the same purpose. This pipe runs from the circumference to the centre on the bottom of the tank, and then straight up three or four feet along the rim; from this project a number of radiating pipes, all of which are perforated with holes to admit of what is technically known as—

THE "SPRAYING" PROCESS.

It sometimes happens, after the oil is in the form of finished product, perfect in color, brilliant and sparkling as could be desired, upon submitting it to inspection to ascertain the "fire-test," it falls short perhaps two or three degrees. A greater discrepancy than this manifests neglect of duty on the part of the distiller, or mismanagement somewhere. Where the difference is not greater than this the difficulty is easily remedied by pumping the oil from one tank to another and allowing it to pass through the *sprayer*. (Fig. 35.) As every particle of the oil is thus exposed to the air in small streams, the small percentage of benzene it

may contain is quickly volatilized and the fire-test correspondingly elevated. It is again tested, and if found satisfactory, it is ready for barrelling. The settling tanks are seldom barrelled from, but are generally connected with

Fig. 35.



The Sprayer.

the warehouse and sheds on the wharf by means of a pipe-line; this pipe may empty into what may be called a reservoir pipe, or a pipe of much larger capacity closed at both ends, with a number of small pipes inserted. To these are adjusted short sections of flexible gum hose supplied with a patented barrelling faucet. By an arrangement of the kind here described, several thousand barrels may be filled daily without waste.

The above process describes the manufacture of the

"standard-white" oil, which is chiefly the oil for export, and made in the largest establishments in this country. An oil inferior to this, and largely sold, is of a lower fire-test, of a pale-straw color. This is generally made by mixing the first runnings of light oils ranging from 64° down to 56° where the flow is cut off in the manufacture of "water-white" and the last runnings after the water-white oil ceases to come over. An oil of this kind will be found to burn well for a short time, but as soon as the lighter portions, which burn first, diminish in volume, the flame droops, and its inferiority manifests itself. Thus we have the two runs of the still, one with the middle cut or the heart of the oil removed, the other retaining all of the illuminating oil. To distinguish the difference between these two oils is impossible by mere inspection of the color, gravity, or fire-test. The inferior oil will bear all of these important tests of a good oil. The only two tests which it will not stand are comparison with a good oil by actual burning in lamps side by side, and an assay by distillation in a small experimental still. The latter test of course cannot be applied by the ordinary consumer, but fortunately the former is easily at his command. It is very important that these two entirely different oils, yet identical in appearance, should be carefully distinguished, the one from the other. The inferior is often sold to the unsuspecting or inexperienced consumer at a price quite disproportionate to its real value. While a "white oil" may not be a safe one, it is always well to reject a dark one.

"MINERAL SPERM" ILLUMINATING OIL.

This grade of burning oil, adapted especially for light-houses and locomotive head-lights, was first introduced to the trade by the Downer Kerosene Works of Boston. It is a dense oil, of about 36° Baumé with a fire-test of 300° F. It is of a light-straw color, and should have but little odor. As originally made, it was a doubly distilled product with very superior illuminating properties, and admirably suited for situations exposed to more than ordinary heat, its high fire-test making it a thoroughly safe oil under these conditions. It is prepared by reserving the distillate from the crude oil, ranging from 40° down to 32°. This is treated in the usual way with sulphuric acid in the proportion of four ounces of acid to the gallon of oil, washed with a solution of caustic soda, and then re-distilled over soda lye. Of course, an oil similar as to density and fire-test may be prepared without a second distillation; such a product, however, will be found to be inferior in its illuminating power to the other.

RE-DISTILLATION AND TREATMENT OF THE BY-PRODUCTS, BENZENE AND RESIDUUM.

The benzene from its lightest gravity down to 62° or 64° is generally collected in one tank. It is either sold to benzene refiners, or may, with the proper apparatus, be re-distilled upon the same premises. For the separation of gasolene (so largely employed in the carburetting machines for the manufacture of gas for the use of dwellings and

factories, remote from gas-distributing centres), no better form of still has ever been devised than the *column still*, employed in the manufacture of alcohol. Its construction and principle are admirably adapted to the separation of the extremely volatile portions of petroleum. In cold weather (and in summer by the addition of ice to the water of the cooler), rhigolene may be collected from the first runnings. This product must be stored either in glass carboys or in tin cans. It has been employed successfully in surgery, for producing local anæsthesia by the actual freezing of the part operated on by the knife. It is chiefly employed in the opening of small abscesses and the extirpation of small tumors. The percentage yield is small, only about $\frac{1}{10}$ of one per cent. (sp. gr. 0.625, boiling point 60° F.). This product has also been employed in the artificial production of ice, in place of ether or ammonia in the "freezing machines." By passing the vapor of rhigolene through a condenser surrounded by a freezing mixture of ice and salt, a still lighter product, known as chymogene, may be collected. This is a gas at ordinary temperatures, and must be kept only in air-tight vessels capable of sustaining considerable pressure. The percentage of yield, sp. gr., and boiling points of these products of the distillation of petroleum are here given :—

	Yield.	Boiling point.	Specific gravity.
Gasolene	1 to 3 p. c.	115° F.	85°–88° B.
Rhigolene . . . . | Chymogene . . .	$\frac{1}{10}$ p. c.	60°	

The distillation of all the benzene products is effected by the introduction of a steam coil near the bottom of the still. In large refineries where the benzene product is very large, the ordinary alcohol column still is quite inadequate to meet the demand made upon it. A modification has been employed including an enlarged form of this apparatus.

The stills used in this connection may be constructed either upon the principle of the cylinder or the cheese-box still, previously described. They are built of wrought iron, and, resting upon a stone or brick foundation, do not require any arrangement for fire places. In large works they are frequently constructed to hold one thousand barrels. The product of this distillation is then distributed in one operation into three different receptacles. The heavier portions, below 62°, are run into the oil tank.

The Deodorization of Benzene

Is effected upon the same general principles which regulate the deodorization of oils, excepting that the agitation is effected by a revolving paddle. The blower is inadmissible here on account of the great loss of material by volatilization. The proportion of oil of vitriol used is also much smaller. One half of one per cent. is ample to effect a thorough deodorization. This deodorized product is generally employed for detergent purposes, for the extraction of grease from all kinds of fabrics, and for other uses where the disagreeable odor of crude benzene is not objectionable.

The Distillation and Utilization of Residuum.

After all the oil that can be safely run into the illuminating oil has been removed from the still, and when the darkened product would impair or imperil the color-test, the fires are usually withdrawn from the still and preparations made to remove the residuum and the coke. Some refiners prefer to continue the distillation a short time longer to recover a small percentage of oil, dark though it may be, which is run over with a fresh portion of crude oil. Where the crude oil is of light gravity this proceeding is unobjectionable and may be profitable; but when the crude oil is of heavy gravity, the propriety is questionable, and its profitableness exceedingly doubtful. In former years it was customary to allow the still to cool for several hours after the fire had been withdrawn. The residuum was withdrawn through a tail pipe at the rear of the still. This could not be done immediately after the fire was withdrawn, as at the high temperature of the contents of the still at the completion of the process of distillation, the residuum would instantly take fire upon exposure to the oxygen of the atmosphere. Several dangerous fires resulted from this early mode of procedure. The residuum is now withdrawn by means of a pipe connected with a steam pump. The pipe passes by several returns of the same through a tank of cold water, which cools the residuum sufficiently to obviate this danger. It is pumped into a large settling reservoir or tank, where it is allowed to stand for several days to allow of the subsidence of all

the fine particles of coke, which will separate by this process. This tank is provided with an exit pipe placed at the distance of about twelve inches from the bottom of the tank, to admit of the drawing-off to the clear liquid, while a large opening or man-hole is placed on the side at the bottom to admit of the removal of the sediment. This is in the condition of slush, and is exclusively employed as fuel for the stills or boiler by mixing the same with fine coal dust or coke screenings. The residuum thus purified is pumped into storage tanks. In this condition it is either sold to the manufacturer of paraffine-wax and lubricating oils, or for the manufacture of gas, for which it has been largely employed, either to enrich the gas product of coal, or by itself.

Treatment of Residuum.

If there were any dividing line between the business of manufacturing illuminating oils and that of making lubricating oils, this would be a proper place to make it, but in practice it is impossible to place this line, as it would be difficult to find two refiners who confine themselves exclusively to the same class of products; while some of the largest manufacturers who formerly devoted themselves entirely to one grade even of illuminating oil, now find it both convenient and profitable to handle most, if not all, of the various products which can be made from the crude oil. We shall therefore pursue the method which we have adopted, of describing the different processes employed, assuming for

convenience sake that all are practised under one management.

After the subsidence of all the coke, the residuum is transferred by means of a pump to the residuum stills. These are generally built on the cylinder pattern, and should not much exceed two hundred barrels' capacity, and are set in banks of three. In stills of larger capacity, it has been found in practice that the quantity of solid coke residue is so great that the heat necessary to drive the still to dryness is so intense as to severely strain the bottom, making frequent repairs necessary. The ordinary forms of condensers can be employed, excepting that the tanks containing the water are furnished with a steam pipe, in order that, in cold weather, the water may be warmed sufficiently to keep the dense paraffine oil passing through the pipe in a liquid condition; otherwise, the pipe may be so choked up with solid paraffine as to endanger the life of the operator from an explosion. In warm weather there is very little risk of this kind, but in extremely cold weather the distiller should be constantly on the alert to discover the first appearance of a stoppage from this cause. If, in weather of this description, the flow of oil is checked, with the ordinary fire under the still, the safest course will be to withdraw the fire, unless the condenser itself is supplied with a steam pipe by which a jet of live steam may be made to pass through the pipes and thus clean them.

In a number of paraffine-oil manufactories, air condensation is employed, and water tanks entirely dispensed with. The condensation is effected through cast- or wrought-iron

pipes of eight or ten inches in diameter, suspended in the air; the pipe rising by a slow gradation as it passes from the still. This pipe is provided with outlets at certain intervals to admit of the removal of the heavier oils, which are the most rapidly and readily condensed. This is, perhaps, a modification of the Atwood condenser.

When the still is loaded, and the fire started, the distillation commences. The first runnings from twenty to twenty-five per cent. (if the residuum be of good gravity), say of 20° to 21° B., will be found sufficiently light in gravity to be transferred to the crude oil tank and re-distilled from this. From that point down to the emptying of the still, paraffine oil constantly pours forth from the tail-pipe of the condenser, gradually deepening in color and increasing in density. If the paraffine oil is to be sold without further manipulation, the whole distillation is generally run into one tank, leaving the further manipulation to the manufactures of paraffine wax and lubricating oils. If the handling of the distillate is contemplated by the distiller of the residuum, another course is pursued, and we here merge our operations into the domains of the manufacture of lubricating oils and paraffine wax, which is in many places quite a distinct business. Here again is a subdivision of this multiform product. The manufacturer of wax selects his crude material from the various samples of heavy oil offered to him, being guided in his choice both by its gravity and color, and the percentage of wax it contains. The manufacturer of machinery or lubricating oils finds himself in a wilderness of oils of all kinds, animal, vegetable, and mine-

ral, the peculiarity of all and each of which he is obliged to make himself acquainted with to adapt them by an infinite number of combinations and mixtures to suit the various tastes, whims, or actual experience of his customers.

Paraffine Wax and its Manufacture.

While paraffine in a fossil state under the names of earth-wax, or ozocerite, has been known in Europe from the earliest times, the modern discovery that it is a product of the distillation of several organic bodies under high temperatures, belongs fairly to the chemist Karl Reichenbach, who gave to the strange compound its present name, from *parum* and *affinis*, because it appeared to him to be wholly destitute of chemical affinities. His discovery, and its peculiar behavior in this respect was published in the year 1830. The following year, its presence in the petroleum of Rangoon, was noticed by Christison, of Edinburgh. He called it *petroline*, but hearing subsequently of Reichenbach's discovery, he was satisfied of the identity of the two substances, and withdrew the name given by himself. In 1833, 1834, and 1835, we have records of the separate discoveries by the three chemists, Laurent, Gregory, and Viobel, the former showing that the oils distilled from shale contained paraffine.

From this time on organic chemistry was making rapid advances, and we have frequent allusions to its presence in a number of compounds as a result of destructive distillation. To no one person does the credit more properly belong of

founding the commercial industry based upon the manufacture of paraffine and its allied products than to Seligue, of France. Largely to his genius and indefatigable industry belong the many improvements made in the manufacture of oil from bituminous shale. Did our space permit, we would be glad to reproduce here Professor F. H. Storer's remarks on the discoveries of Seligue in connection with the paraffine industry. We have room only for the following brief extract, which succinctly details the various products secured by him :—

"On the 27th of March, 1839, Seligue specifies certain additions and improvements to a former patent. In alluding to the use of his oils in the treatment of cutaneous diseases, he speaks of the three large establishments for the distillation of bituminous shale, which he has erected in the department of Saône et Loire, and mentions the fact that the oil (crude) is furnished at the rate of ten centimes per pound. The clearest of all of Seligue's specifications, however, is that of the patent granted to him March 9, 1845, for the bituminous shales and sandstones. After describing the various forms of apparatus used in distilling, into one of which superheated steam was introduced, he enumerates the products of distillation as follows: I. A white, almost odorless, very limpid mineral oil, somewhat soluble in alcohol, which may be used as a solvent or for the purpose of illumination in suitable lamps. II. A sparingly-volatile mineral oil of specific gravity 0.84 to 0.87, of a light lemon-color, perfectly limpid, almost odorless, never becoming rancid, and susceptible of being

burned in ordinary lamps having an elevated reservoir, with double current of air, a slight modification of the form of the chimney and burner being alone necessary. This oil also can be mixed with the animal or vegetable oils. Oils thus prepared do not readily become rancid, nor do they congeal easily when subjected to cold. III. A fat mineral oil, liquid at the same temperature as olive oil. This oil contains a little paraffine, it is peculiarly adapted for lubricating machinery, and has an advantage over olive and other vegetable oils, or neat's-foot oil, in that it preserves its unctuousness when in contact with metals, and does not dry up. It saponifies easily, and forms several compounds with ammonia. IV. From the oils I., II., and III., I extract a red coloring matter which can be used in various arts. V. White crystalline paraffine, which needs but little treatment in order to be fit for making candles. This substance does not occur in very large proportion in the crude oil, and the proportion varies according to the different mineral substances upon which I operate. There is but little of it in petroleum and in the oil obtained from bituminous limestone. I often leave a great part of the paraffine in the fat oil, and in the grease, in order that these may be of superior quality. VI. Grease. This grease is superior to that of animals for lubricating machinery and for many other purposes, since it does not become rancid and remains unctuous when in contact with metals. VII. Perfectly black pitch, very "drying," suitable for preserving metals, wood, etc. VIII. An alkaline soap obtained

by treating the oils with alkalies. IX. Sulphate of ammonia. X. Manure, prepared by mixing the ammoniacal liquor or the blood of animals with the crushed fixed residue (coke) of the shale. XI. Sulphate of alumina from the residue of the shales." This specification contains also a description of his apparatus and the details of the treatment which contained the acid and alkali washings. We find in the above patent the key to many if not most of the methods employed not only in the subsequent manufacture of shale oil, but also to those more recently adopted in the treatment of petroleum oils. Of course, many of his processes have been modified, but when we consider the intractable material he had to deal with and the entire absence of any previous light upon his pathway, we must fairly accord to Seligue a high position if not that of the father of this industry. We have alluded in another connection to the part taken by Mr. James Young in the introduction and manufacture of Boghead coal oil in Scotland and England, which in the year 1878 reached large proportions, consuming 800,000 tons of coal shale, and producing 30,000,000 gallons of crude coal oil, subsequently converted into illuminating oil, machinery oil, paraffine, etc.

In this country paraffine is wholly a by-product in the manufacture of lubricating oils, or in the treatment of the heavy oils proceeding from the distillation of petroleum towards the last of the process. The purification of crude fossil paraffine, as practised in Europe, does not fairly claim our notice here, except we can discover in any of the

methods employed there, anything which will aid us in our present work.

In treating this subject from the stand-point of the American refiner, the preparation of lubricating oils and the manufacture of paraffine wax run so closely together, that in some points at least they touch, and must be treated as though they belonged to one subject. The manufacture of either or both begins when the residuum is placed in the still. The first products of this distillation down to about 32° Baumé (which when they are received into one tank, constitute an oil of 38°), are returned as crude oil.

The Production of Illuminating Oils.

After the separation of this first part, the products of the still are either again subdivided into at least two runnings, or run into one tank, according to the peculiar views of the refiner and the wants of his customers. If received into one tank, the oil is pumped into the "paraffine agitator." This apparatus is constructed upon the same general principles as the agitator used for illuminating oil, excepting that it is provided with special arrangements for heating its contents and retaining the dense easily congealed oil in a liquid condition. This is readily accomplished by surrounding the agitator with a steam-jacket, which not only supplies the facilities for applying the heat when required, but also affords a protection to the sides of the tank from the chilling effects of the cold during the winter. In the absence of this, in very cold weather, it will be almost impossible to treat

paraffine oil on account of the solidification of the paraffine upon the internal surface of the tank; no more heat should be employed than is actually necessary to maintain the contents in a fluid state, and the paraffine entirely melted. The same general principles of chemical treatment followed in the case of illuminating oil are observed here. The amount of acid used is much larger, and is regulated by the gravity and color of the distillate. Three, four, or even five per cent. in volume is employed. Its action upon the oil is very energetic, accompanied with the disengagement of an abundance of sulphurous acid vapor, and the subsidence of a heavy "acid sludge," requiring exit-pipes and stop-cocks for drawing it off, to be of larger diameter than those ordinarily employed. The "sludge" upon standing becomes quite solid, and is entirely a waste product. This treatment is followed by the usual water- and alkali-washing. Care should be taken throughout, that the proper temperature be preserved, so that the paraffine shall be maintained in perfect solution. When this operation is completed, the oil is either allowed to flow by gravity, or it is pumped into tanks, provided with a steam coil, in order that its contents may be preserved in a perfectly limpid condition to permit of the settling of the water. This being withdrawn through a stop-cock at the bottom of the tank, the contents are removed to another apartment, the temperature of which has been artificially lowered by a freezing machine, where it is subjected to the chilling process.

In the winter the ordinary temperature is sufficient to crystallize the paraffine. If the process is to be carried on

during the warm weather, the contents of the tank are barrelled, and the temperature of such a room may be reduced by a good apparatus to 10° or 15° F., even in very hot weather. An exposure of the paraffine oil for forty-eight hours to this temperature chills the whole mass to a complete solid. From the packages, the contents are shovelled out into small cotton bags of very strong material and subjected to powerful pressure by means of a hydraulic press. This pressure is slowly applied and gradually increased, the operation being one requiring skill and experience. If the pressure be too rapid and too severe, especially at the commencement, a notable percentage of paraffine crystals will be forced through the interstices of the bagging, attended also, probably, with a rupture of the same, and a serious contamination of the oil that has already passed through. Unless this operation be skilfully conducted, enough crystallized paraffine, it may be in very fine particles, will pass through the bagging, to interfere materially with the "cold-test" of the oil. In the event of a difficulty of this kind, simple straining through coarse muslin will frequently remove these coarse particles of floating crystals. This operation must of course be done in an apartment where the temperature is sufficiently cold to prevent their melting.

We have now divided the product of the distillation of the residuum into three parts: 1st. The lighter oils, which have been returned to the crude oil tank. 2d. The crude paraffine, which for the present we leave in the presses; and 3d. The refined heavy oil, which in its present shape may be either sold for lubricating purposes, or subjected to

further treatment for special purposes. The gravity of this should be about 32° B., and the fire-test 325°, and the cold-test 30° F.

Quite a high temperature is necessary to drive all the volatile portions of the residuum, and before the residue of this is completely converted into coke, the bottom of the still becomes red-hot, and yellow vapors issue from the tail pipe; very near the close of the operation the redistils over a dense, resinous, product of a light-yellow color, of a solid consistence in even moderate weather, and becoming quite brittle in cold weather. It readily sinks in water, having a specific gravity of about 1.25. It exhibits in a very high degree the iridescent properties of petroleum, to such extent indeed, that it has been supposed by some to be the peculiar compound which imparts to petroleum its rainbow hues. Professor Morton, of the Stevens Institute of Technology, who investigated its properties some years ago, obtained from it two bodies, exhibiting a high degree of fluorescence, for which he proposed the names, *thallene* and *petrolucene*. As it readily dissolves in paraffine oil, it has been added to these for the purpose of increasing their density for lubricating purposes.

For the present, we leave the further consideration of lubricating oils, and having obtained paraffine in a crude state, will take up the process of

Refining Paraffine Wax.

From the refined paraffine oil, prepared and chilled as above described, there should be obtained about three-

quarters of a pound of crude paraffine to each gallon of oil. The color and appearance of this will of course depend greatly upon the character of the oil from which it has been separated. When removed from the bags in which it has been pressed, it is somewhat variegated in color, some portions being of a light lemon, others presenting quite a greenish hue ; the crystalline appearance thoroughly broken down by the immense pressure to which it has been subjected. The contents of the bag are thrown into a steam tank, where it is melted by live steam, one per cent. of soda-ley is added, and the whole thoroughly steamed, the condensed water withdrawn, and, when sufficiently cool to admit of the process, about 25 per cent. of benzene is added, and the whole vigorously stirred until a homogeneous mixture is obtained. The contents of this tank are ladled out into shallow tin pans holding about five or ten gallons each, which are allowed to remain in the cold-air room for three or four days. This product is again expressed in clean bags. The paraffine thus obtained is in large crystals with a slight tinge remaining, and having a much higher melting point (about 130° F.) than the crude article first described. The expressed "mother liquor," from this second operation, is either run into the "stop tank" (which is a convenient receptacle for a variety of wastings, small residues of sundry distillations, etc.), or thrown back into the benzene tank for use a second time. The contents of the "stop tank," when sufficient stock has accumulated, is pumped into a still, which is generally kept for the special purpose, and the distillates proceeding

from this are distributed according to their character. If the density should admit of it, a large percentage may be thrown direct into the tank containing illuminating oil.

Another process for the purification of crude paraffine has been employed, which is perhaps more expeditious and also more economical, but is not quite so satisfactory in its results. This consists in grinding together benzene and paraffine into a magma, which is subsequently submitted to the usual pressure. This process, which is analogous to that employed in chemical laboratories, and known as "washing crystals," is repeated until the pressed mass is white enough for ordinary purposes. For the further purification of the paraffine obtained either by this or the former process, the wax is placed in a suitable tank and gently heated, with the addition of from three to five per cent. of animal charcoal. The whole is thoroughly agitated by an air-blower for several hours. The coarser particles of charcoal are allowed to subside, and the melted wax filtered hot through a wire-gauze filter, which is lined with flannel, the filtrate passing as colorless as distilled water.

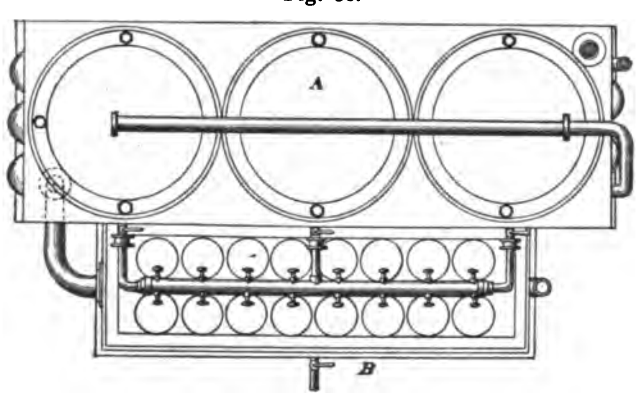
Other refiners rely largely upon the purifying action of oil of vitriol for obtaining a white product. For this purpose a wax partially purified by re-crystallization from benzene and pressure, is selected. The same is gently heated to its melting point, when about five per cent. of sulphuric acid is gradually added while brisk agitation is sustained. The action of the acid upon the melted wax is even more violent than upon the paraffine oil, and some arrangement is necessary to carry off the abundant

vapors of sulphurous acid which are disengaged. This can be accomplished by covering the agitator with a hood, which will conduct these suffocating vapors into a chimney-stack. The same arrangements for keeping the contents of the vessel warm, which were needed in treating heavy oil, are needed here. After half an hour's treatment, the heavy acid is drawn off at the bottom, a hot solution of soda-ley (five per cent. of a solution 12° Baumé) is added. The agitator is again put in motion, and the melted wax thoroughly treated, the soda-washing is withdrawn from the bottom of the tank which is kept warm, until it has completely settled and the contents are bright and clear. The wax is run into large flat cakes, which, when cool, have a fine pearly lustre, and are nearly colorless.

Decolorization through the agency of "bone-black" appears to offer the most perfect results. This process, however, is only employed upon paraffine which has been partially whitened either by repeated crystallization, or by the acid process, or by a combination of both processes. To accomplish this upon a manufacturing scale commensurate with the demand, a number of plans have been suggested. Perhaps the most complete of these is Ramdohr's filtering apparatus, which is constructed to filter about 2500 pounds per day. As it is inexpensively made and easily duplicated, it appears to supply the need. The following description is taken from 'Dingler's Polytechnic Journal.' The engravings which illustrate the machine are sufficiently clear without repeating here the whole article.

"This has the following peculiarities in its arrangement: 1. The mixing of the paraffine with bone-black does not take place by the hand or through a mechanical stirring contrivance, but through a warm current of air previously blown into the apparatus. 2. The paraffine treated with bone-black flows of itself into the filter paper placed in a glass funnel, and, after the influx has once been regulated, the operation proceeds without demanding special attention on the part of the workman. Even if, at times, less permeable paper should be accidentally placed in the filter, this, from the inattention on the part of the workman, cannot easily cause an overflow of the paraffine, while the greater or less permeability of the paper is easily observ-

Fig. 36.

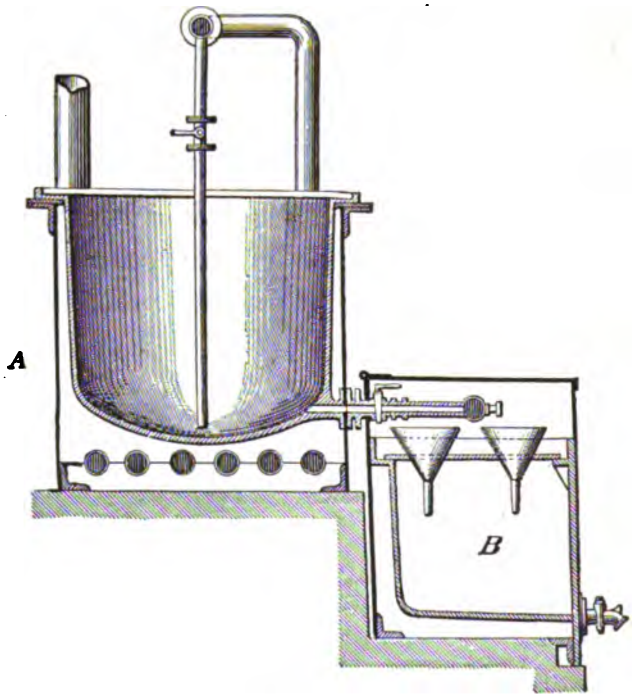


Ramdohr's Paraffine Filtering Apparatus.—Horizontal Section; *A*, Mixing Apparatus; *B*, Filtering Apparatus.

able during the first half hour, and the feed-cock should be adjusted accordingly by the workman. 3. The whole apparatus is heated by waste steam. 4. The mixing and filtering apparatus occupy little space. *A*, in Figs. 36 and

37, represents the mixing apparatus; *B*, in the same figs., the filtering apparatus. The steam first enters the filtering apparatus, and then passes through the mixing apparatus into the open air. The mixing apparatus consists of a

Fig. 37.

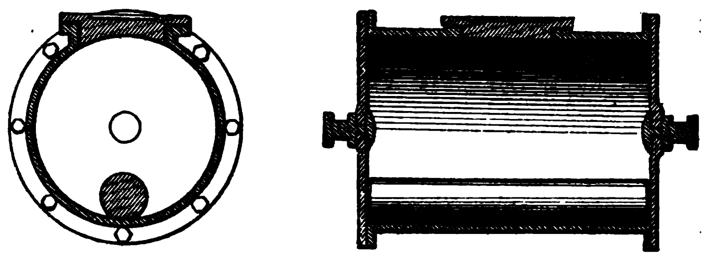


Ramdohr's Paraffine Filtering Apparatus.—Vertical Section; *A*, Mixing Apparatus; *B*, Filtering Apparatus.

wrought-iron chest with a turned cast-iron flange covered with iron cement, in which are three openings for the admission of three cast-iron mixing kettles. These kettles are fastened to the flange of the steam chest by a few screws in order to prevent any displacement which an insecurity

of the discharging vessel would cause. The kettles with the steam chest are rendered steam-tight in the simplest manner by a band of rubber placed beneath the rim of the kettle.

Fig. 38.



Ramdohr's Charcoal Pulverizing Drum or Cylinder.

A sufficient charge of partially refined paraffine is placed in the mixing tank, and, when thoroughly melted, from three to five per cent. of finely-granulated and freshly-burned animal-charcoal is added, and kept in suspension by a current of warm air passing through the pipe. The supply of melted wax passing to the filtering funnels is regulated by the large stop-cock nearest to the tank, and the quantity flowing into each funnel is adjusted by a separate and smaller stop-cock. The apparatus, which is said to do its work effectually, can be readily duplicated, and the capacity of the works indefinitely increased.

Lubrication and Lubricating Oils.

The advantages, both pecuniary and beneficial, accruing to modern civilization, from the introduction of the heavy products of petroleum used for the lubrication of machinery,

are hardly second to those resulting from the introduction of the cheap and beautiful light furnished by its illuminating portion. It would be difficult to exaggerate its importance and value to the textile manufacturer, to the iron industry, and to the railroad interests. The hydro-carbon oils, for the purpose of lubrication, were at first received with but little favor, indeed, the opposition was all but universal. The disagreeable odor always associated with the imperfectly prepared oils first offered, disinclined superintendents of mills and factories to give them a trial even at prices much lower than those which they were accustomed to pay. Insurance companies on account of the explosive inflammable vapors, said to be inseparably connected with them, refused to take risks, except at greatly increased rates, upon factories where they were employed. The objections urged against their introduction were not wholly without foundation, and incited the manufacturers to increased diligence in removing them. Improved methods of treating these oils soon resulted in greatly improved products; the prolific yield of the crude material from the wells still further reduced their market price. Accurate methods of testing their real economic value were discovered and introduced into use, and thus through their real merit in the face of, often ignorant, opposition, these oils have made their way into general use and favor. It is not to be inferred from what has been said, that animal and vegetable lubricating oils are driven from the market, or are likely to be. They have distinctly important uses, and, whether alone, or combined with hydro-carbon oils, will still

be employed for the purpose of lubrication. Nothing has contributed more rapidly and more effectually to disarm the ignorant opposition before alluded to, than the accurate tests of their working value to which all kinds of machinery oils are now subjected. These have resulted not only in discovering desirable qualities in the hydro-carbon oils hitherto unsuspected, but have pointed out methods by which objectionable features have been either wholly removed, or greatly modified. These tests have also drawn a marked line of distinction between the empirical manufacturer of machinery oils, and he who is thoroughly abreast with the march of scientific knowledge, and the advances of manufacturing skill. The day is past when the former, through "oily" persuasion or incorrect representations (whether intentional or otherwise), can successfully impose his products upon large mill-owners or railroad companies. However willing these corporations may be to buy at "bottom prices," the goods *must* stand the prescribed tests, which are severe and operate without fear or favor. Upon soliciting trade from such large consumers, a sample is furnished, the tests are applied, whereupon, if the quality is up to or above the prescribed standard, and the price is satisfactory, then, and then only, is there a chance of the introduction of a new brand of oil. Oil manufacturers sometimes complain of "corruption in high places," but in the long run, nothing will withstand "best goods, bottom prices, and full measure." This is a kind of competition, the intelligent, skilful, honorable dealer loves to engage in; he is more than pleased to have those tests applied, which will expose

the frauds and adulterations of his less scrupulous competitor, who would only be too glad to avoid a disclosure of some of the "tricks of trade" familiar to, and practised by him.

In a work designedly written upon petroleum and its products, an exhaustive article on all of the materials employed as lubricants cannot be looked for, but the combinations or mixtures of animal or vegetable oils, or other lubricants, with petroleum, are so common and varied, that it will be impossible to avoid all reference to this class of oils.

Characteristics of a good Lubricant.

Professor R. H. Thurston, of Cornell University, in his 'Treatise on Friction and Lost Work in Machinery and Mill Work,' furnishes the following characteristics of a good lubricating material:—

1. Enough body, or combined capillarity and viscosity, to keep the surfaces between which it is interposed from coming into contact under maximum pressure.

2. The greatest fluidity consistent with the preceding requirements, *i. e.*, the least fluid friction allowable.

3. The lowest possible coëfficient of friction under the conditions of actual use, *i. e.*, the sum of the two components solid and fluid friction should be a minimum.

4. A maximum capacity for receiving, transmitting, storing, and carrying away heat.

5. Freedom from tendency to decompose or to change in

composition, by gumming or otherwise, on exposure to the air or while in use.

6. Entire absence of acid or other properties liable to produce injury of materials or metals with which they may be brought in contact.

7. A high temperature of vaporization and of decomposition and a low temperature of solidification.

8. Special adaptation to the conditions as to speed and pressure of rubbing surfaces, under which the unguent is to be used.

9. It must be free from grit and from all foreign matter.

The consumer will readily recognize in the above all the desirable qualities that he requires, and the manufacturer those points of excellence he aims to secure in his manufactured products. As to what lubricant to use under certain specified conditions of temperature, speed, and pressure, a practical trial under these conditions will be the best teacher; but such a trial, often involving considerable sacrifice of time and money, may not be expedient, and we are therefore governed by some such general rules as Professor Thurston furnishes:

"The best lubricants are in general, the following, for usual conditions met in practice.

"Under low temperatures, as in rock-drills driven by compressed air, light mineral lubricating oils.

"Under very great pressure with slow speed, graphite, soapstone, and other solid lubricants.

"Under heavy pressure with slow speed, the above and lard, tallow, and other greases.

"Heavy pressure and high speed, sperm oil, castor oil, heavy mineral oils.

"Light pressure and high speed, sperm, refined petroleums, olive, rape, and cotton-seed.

"Ordinary machinery, lard oils, tallow oils, heavy mineral oils, and the heavy vegetable oils.

"Steam cylinders, heavy mineral oils, lard, tallow.

"Watches and other delicate mechanisms, clarified sperm, neat's-foot, porpoise, olive, and light mineral lubricating oils.

"For mixture with mineral oils, sperm is best, lard is much used, cotton-seed and olive are good."

While the consumer must be guided to some extent by such general directions as are given above in determining which of the several varieties is the best oil for his use, he must have either the requisite apparatus to test his oil and the skill to use it himself, or he must rely upon the skill and honesty of the manufacturer. The number of machinery oils and their combinations are beyond enumeration. In large cotton and woollen mills, the risk of fire from spontaneous combustion is an important consideration in the selection of oils, both for purposes of lubrication and for oiling wool. Indeed, so important is this, that the Boston Manufacturers' Mutual Fire Association commenced, in the year 1878, a general examination of the oils offered to manufacturers and their relation to losses by fire. The investigation was conducted by Professor J. M. Ordway of the Massachusetts Institute of Technology, and so fully covered all the points under discussion as to make the

report offered by him probably the most exhaustive and valuable paper yet published on this subject.

Professor Ordway was commissioned to inquire into the character of the oils with reference to—

1. The power of the oils to diminish friction under various pressures and at various rates of speed.

2. The tendency of the oils to oxidize while in use for lubrication, and their consequent deterioration in efficiency.

3. Their tendency to rapid oxidation when largely extended by absorbent fibrous substances, and their consequent liability to induce spontaneous combustion.

4. Their proneness to emit combustible vapors when rubbed or moderately heated or kept in partially filled reservoirs.

5. Their tendency to corrode metallic bearings.

6. Their specific heat, or relative rapidity of heating and cooling, when exposed to the same heating or cooling influence.

7. The relative length of time that a pint of each will last in doing a given kind of lubricating work.

8. Their relative fluidity, or the thickness of layers retained between two surfaces subjected to a given pressure.

9. Their compatibility with each other when successively used on the same bearing.

10. Liability to separate into constituent parts by long standing or by freezing.

11. Their freedom from non-lubricating sedimentary matter.

12. Ease of removal from bearings after becoming

thickened by floating dust, or abraded particles of metal, or by accidental over-heating.

13. Their tendency to diffuse unpleasant or unwholesome odors.

14. Ease of ignition and rapidity of combustion when they are inflamed.

15. The probability of perfect uniformity in successive lots supplied by the manufacturer.

16. The possibility of securing an unlimited supply at moderate prices.

17. Suitableness for oiling wool before weaving and spinning.

18. Ease of removal from yarn or cloth in the operation of scouring.

19. Their suitableness for the manufacture of soaps.

20. Their effect on leather and wool.

An examination of this list of subjects and inquiries very clearly shows the various difficulties these manufacturers had to contend with, in using the different kinds of oil offered for sale. One hundred and eighteen different samples were obtained, not from the dealers, but from the manufacturers, who took them from their stock on hand.

There were samples of "spindle oils," "sperm oils," "paraffine oils," "lard oils," "stainless oils," "neat's-foot oils," "machinery oils." The samples were all numbered, and the specific gravity of each accurately determined. We have only space to note here the general conclusions arrived at. These are important, and enable us to appreciate the accuracy and value of the various tests employed, also

to recognize the fact that these are to be relied upon only when they are taken collectively. For example, the sp. gravity of a fine-looking specimen of spindle oil will not alone determine its value, its fire-test is equally important; next, its viscosity is a subject of considerable importance. It was discovered that many samples (afterwards shown to be composed wholly or in part of petroleum) lost in bulk rapidly when exposed in open dishes even to the ordinary temperature of the work-room. Experiments were made upon these at a temperature of 140° Fah. This degree of heat is often felt in proximity to a steam pipe. These experiments were made in watch-glasses, and all of the samples were subjected to the same test. One specimen of "spindle-oil," price 48 cents per gallon, lost in 12 hours' exposure, nearly 25 per cent. Twenty samples out of the lot lost over 10 per cent. When the temperature was raised to 200° the loss, in some cases, was as high as 37 per cent. Other oils, evidently of animal or vegetable origin, submitted to the same temperature, instead of losing weight actually gained, in some instances as much as 2½ per cent. Mixtures of light and heavy petroleum did not lose in weight in proportion to the quantity of the former, the heavy oil appearing to have a power of retarding the evaporation of the lighter constituent. The danger from fire consequent upon the inflammable vapor thrown from a thousand bearings is too evident to escape observation. Numerous destructive fires have resulted from the use of oils of this description. The "flashing point" of all the samples was above the boiling point of water; but it is

well known that in some positions in a factory, as for instance near a pipe heated by high-pressure steam, an oil with a flashing point of 212° would not be safe; an inflammable vapor would certainly diffuse itself through the room. The flashing point does not indicate the proportion of light oil. It was found that this varied in the samples examined, from 239° to 450°, "but on putting the figures side by side with those that represent the loss by evaporation, we find the flashing point does not indicate the loss we should expect by evaporation. There is a wonderful difference. I find there is one which lost by evaporation 4.6 per cent., and it had the same flashing point as one that lost by evaporation 13.8 per cent. We find another which lost 9.4 per cent., and yet it flashed at the same heat as one that lost 24.6 per cent. This would seem to show that the flashing point is not to be so much relied upon. I place a good deal more reliance on the other experiments, to long exposure in contact with the air at a given temperature, and the flashing point I should set down as one of the things that may give uncertain results. If any oil has a low flashing point it ought to be rejected, but at the same time an oil bearing a high flashing point may be mixed with a certain amount of a lighter oil which will freely evaporate when exposed to the air more rapidly than another oil with a low flashing point."

Dangers from Spontaneous Combustion.

The tendency of the animal and vegetable oils to absorb oxygen from the air, causing "gumming" in machinery oils,

has already been adverted to. When this class of oils is mingled with wool, or with cotton waste, in about the proportion of their absorbent power, and left exposed to the air, the danger from spontaneous combustion becomes very great. The introduction of hydro-carbon oils, either as a component of machinery or wool oils, or as a complete substitute, has largely lessened this danger. The experiments of Mr. Coleman, of Glasgow, and M. Dolfus in Alsace, show that when an animal or vegetable oil is mixed, even in small proportions, with petroleum, the danger is greatly lessened, and when this amounts to 50 per cent. it is wholly avoided. The experiments of Professor Ordway would appear to confirm this view except under some conditions where cotton-seed and linseed oils were used. These oils appear to be exceedingly prone to oxidation, and, when diffused through cotton or woollen waste, especially liable to excite spontaneous combustion, but even with these oils this tendency is greatly lessened by mixture with mineral oils.

Mineral lubricating oils are divided into groups:—

1. Natural oils requiring no treatment.

2. Natural oils requiring only exposure to the air for the removal of adhering light vapors.

3. Natural oils reduced by steam heat in open vessels.

4. Crude oils reduced in gravity in a distilling apparatus.

5. Distilled oils obtained either by the distillation of residuum, or by the subsequent condensation or reduction of some of the heavier distillates. Oils of this class all undergo chemical treatment with acid and alkali washing.

These groups contain all the different varieties which are found in the market under a multitude of names, and are unmixed oils. In addition to these there is a large class of mixed lubricants, or combinations of petroleum with animal or vegetable oils, some of which are fluid, while others partake of the nature of greases. Some of this latter class are combinations with rosin-oil compounds, some are saponaceous compounds, others are mixtures of plumbago, talc, clay, etc., finely ground.

Professor Thurston thus speaks of the mineral-machinery oils: "The consumption of petroleum or mineral lubricating oils is largely increasing. They are used on all kinds of machinery; they are the safest and cheapest lubricators, and generally superior to animal and vegetable oils and greases. They are safer on account of their non-oxidizing properties and their high fire-test, or the great heat they will resist before vaporizing. They are cheaper in price and more economical, saving both machinery and fuel. They are more reliable, as they are usually pure and uniform in quality. They last longer and work cleaner, and are perfectly free from acids and all impurity. They neither gum nor stain materials or the manufacturer's products." According to Spon's "Encyclopædia of Arts:"

1. A mineral oil flashing below 300° F. is unsafe.

2. A mineral oil losing more than 5 per cent. in ten hours at 60° or 70° F. is inadmissible, as the evaporation creates a gum, or leaves the bearing dry.

3. The most fluid oil that will remain in its place, ful-

filling other conditions, is the best for all light bearings at high speeds.

4. The best oil is that which has the greatest adhesion to metallic surfaces and the least cohesion in its own particles; in this, fine mineral oils stand first, sperm oil second, neat's-foot oil third, and lard oil fourth; consequently the finest mineral oils are best for light bearings and high velocities. The best animal oil to give body to fine mineral oils is sperm oil. Lard oil and neat's-foot oil may replace sperm oil when greater tenacity is required.

5. The best mineral oil for steam cylinders is one having a density of 0.900 and a flashing point of 540° F., with burning point of about 600° F.

6. The best mineral oil for heavy machinery has a density of 0.890 and a flashing point of 360° F.

CLASS I.—NATURAL LUBRICATING OILS REQUIRING NO TREATMENT.

The amount of oil suitable for general lubrication without some manipulation is very small in comparison with the quantity used for that purpose. Oil below 32° Baumé is generally classed among machinery oils. Of course, the lower the specific gravity of the oil the larger the proportion of lubricating oil, but oils of 32° and over are generally distilled for the recovery of a portion of illuminating oil. Besides a number of places where the amount of oil obtained below 32° has been inconsiderable, the following localities have produced heavy grades of oil in commercial quantities:—

Mecca, situated in Trumbull County, Ohio. The wells in this locality are rarely more than 100 feet deep; the oil has a specific gravity of 26° Baumé.

Erie County, Pa. A few wells near the lake shore have produced oils of a superior quality, 26° to 27° B. The quantity, however, is small. Gas wells are numerous in this section.

Franklin, Pa., has been celebrated for its wells of natural lubricating oils.

Smith's ferry, in Beaver County, West Virginia. From this district a peculiar amber-colored heavy oil is produced.

Greensburg, Westmoreland County, Pa. Quantity small.

The Belden district in Lorain County, Ohio. There are a number of wells producing an oil from 26° to 28° B.

Parkersburg, Wood County, West Virginia, has been very productive of heavy oils of excellent quality.

Charlestown, on the Great Kanawha River, West Virginia, is quite a depot for the distribution of the same class of oils.

Monticello, Kentucky, has yielded some excellent oil of 25° Baumé.

The Cumberland River and its numerous tributaries have produced large quantities of heavy oils.

The West Virginia Transportation Company appears to make a specialty of handling oil according to its gravity. Special inspectors are appointed who carefully grade the oil according to the following directions:—

"In receiving and making delivery of oils shipped by the

company the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzene and subjecting the mixture to 120° F., in a graduated glass vessel, for not less than six hours, after which the mixture cools and settles, not less than two hours for light grades, three hours for A grade, four hours for B grade, six hours for C grade, eight hours for D grade, and eighteen hours for heavier grades." Of course the denser the oil the longer time required for the separation of water and earthy impurities. The following are the grades with an approximation as to gravity.

A. 37.1° Baumé and lighter.
B. 33° to 37° B.
C. 31.6° to 32.9° B.
D. 30.6° to 31.5° B.
E. 29.6° to 30.5° B.
F. 28.6° to 29.5° B.
G. 28.5 and heavier.

There has also been observed a very great difference between the temperatures at which these natural oils congeal or become partially solid, their value as lubricators greatly depending on this; the lower the cold test, the more valuable the oil. In this respect, the oils received from the Mecca and Franklin districts are superior to all others. In many cases, this thickening does not seem to be attended with any deposition of crystalline paraffine; nevertheless this tendency to thicken with cold greatly impairs its value as a lubricator, and consequently lowers its market value.

Natural lubricating oils, even of low gravity, will not

always stand the requisite fire-test necessary for their employment either as cylinder oils, or in confined places, where the inflammable vapors induced by friction of journals would be dangerous. It has therefore been found necessary to bring these up to a standard in this respect, to subject them to a certain amount of exposure.

Class II.—Natural Oils requiring only Exposure to the Air for the Removal of Adhering Light Vapors.

Crude oils of 30° and under are selected for this simple treatment. For this purpose, oblong iron tanks are employed, sixty or seventy feet long, twenty or thirty feet wide, and about twenty-four inches deep. These are partially filled with water, sometimes for the purpose of facilitating the deposition of earthy impurities. The crude oil is allowed to flow into a tank of this description and is exposed to the action of the sun and air for twenty-four, thirty-six, or forty-eight hours, the gravity and fire-test being tried from time to time. This is the simplest process to which natural oils are subjected; they are easily reduced several degrees in gravity with a corresponding elevation of fire-test.

Mr. George Allen, of Franklin, has patented an ingenious and novel method of reducing natural oils, which is said to produce an oil of excellent quality. His process is thus described: "He suspends sheets of loosely woven cloth vertically above troughs in a heated chamber, and by a perforated pipe distributes the oil upon the upper border of the curtain in thin streams. The oil is thus distributed

over a large surface in the heated atmosphere, and the thin film is rapidly evaporated, the light portion passing into the atmosphere, and the heavy portion dipping from the lower border of the curtain into the troughs from which it passes into a receptacle. This method of treatment furnishes a bright-green odorless oil, entirely free from sediment of any kind, the impurities remaining attached to the curtain. These methods of reducing oils, involving neither distillation nor artificial heating, are highly to be recommended, as the injurious effects resulting from the decomposition of the oils by such heating are entirely avoided. Oils reduced by either of the above processes are sometimes filtered through animal charcoal, by which they are greatly improved in color, and somewhat, also, in odor. Their quality as lubricants, however, is not affected, as they gain neither in gravity nor fire-test.

Class III.—Natural Oils reduced by Steam Heat in Open Vessels.

This process is very similar to that described in No. 2. The large oblong tanks are provided with coils of steam pipes. The tanks are partially filled with water, and the crude oil is allowed to flow upon, and cover this, to the depth of one or two inches. The oil is heated to the temperature of 110°, when it becomes very limpid, and every particle of impurity quickly subsides. By this arrangement an oil of 32° B. is reduced in two or three days to 28° or 29° without any impairment of quality. The loss sustained in volume,

in either of the above processes, varies, of course, according to the gravity of the oil operated on, and ranges from 10 to 15 per cent.

CLASS IV.—CRUDE OILS REDUCED IN GRAVITY IN A DISTILLING APPARATUS.

The processes by which oils of this description are produced are almost inseparably associated with the manufacture of illuminating oil. It would be wasteful of material to attempt the reduction of an oil of 32° B. and upwards by the open-air process. Therefore, it is better to place oils of this gravity in the still usually employed for illuminating oil. A very gentle heat, either direct or by a steam coil, with or without perforations in the still, is employed, and the heat should not reach the point at which destructive distillation takes place. The evaporation is continued until the requisite density is obtained. About 20 per cent. of distillate is obtained in the reduction of an oil of 32° B. to one of 28°. This distillate contains a small percentage of very light oil, but the whole of it may usually be run into illuminating oil. For use on large journals with a moderate speed, a gravity of 28° or 29° is sufficient. If the oil is intended for high speeds, with considerable pressure, or for cylinder lubrication, the evaporation and distillation should be carried further, yielding a large percent age of distillate, and the resultant product should indicate a gravity of 26°. To proceed thus far, the distillation requires a much higher degree of heat, with the attendant danger of burning the contents of the still. At this point

perforated steam pipes should always be employed, as the escaping steam greatly aids in a mechanical way in carryign over into the condensing worm the condensed oil vapors, thus preventing their return to the hot oil, to be "cracked" and decomposed.

Oils thus reduced are to be found in the market in immense quantity, ranging in gravity from 32° to ordinary residuum. The tests by which these are examined will be discussed under their appropriate head. After the reduction to the proper gravity the oil is removed to a settling tank, where the temperature should not be suffered to fall below 120° F. for several days, to allow of the subsidence of any water, earthy matter, or minute particles of coke. The oil thus produced is of a dark-brown color by reflected light; when poured from a vessel in a fine stream and examined through a bright transmitted light, it has a ruby-red color. It is an excellent lubricator for cylinders, car-wheels, and heavy machinery. It can be readily prepared, of a gravity of 26°, and a fire test of 600° to 650° F. If the heat has not been excessive, it should be nearly free from odor. This oil is sometimes passed through animal charcoal, whereby its color and odor and general appearance are greatly improved, without, however, addiug anything to its value as a machinery oil. The animal charcoal is placed in iron cylinders 10 or 12 feet high and 2 or 3 feet in diameter.

Class V.—Distilled Oils.

These oils are obtained either by the distillation of residuum, or by the subsequent reduction of some of the heavier

distillates. Oils of this class all undergo chemical treatment with acid and alkali washing.

On page 291, under the head of the manufacture of paraffine wax, we brought the subject of the distillation of residuum to the point, where leaving the expressed heavy oils we followed up the subject of the manufacture of the wax. We now propose in this connection to resume the further consideration of those expressed oils.

SPINDLE OILS.

Distillers of residuum usually divide their products into three classes:—

1, an oil of about 38° B.	constituting	23	per cent.
2, " " " " 31° to 33° B.	constituting	25	per cent.
3, " " " " 22° to 24° B.	"	41	" "
Loss in gas and coke		11	" "

The first of these distillates is returned to the crude oil tank. The second product is either re-distilled for another subdivision, or employed as a basis for "neutral oil," which we will presently notice. The third and last product constitutes the stock for spindle and machinery oils. If the oil which has been separated from the paraffine by pressure has been properly treated by chemicals, it should be nearly odorless and of a light orange-red, with a gravity of about 22° B., with a cold-test of 30° F., and a fire-test of about 360°. The viscosity of such an oil should be about 130. This oil may be improved in appearance and quality by submitting it to the following treatment. Percolation

through bone-black will greatly lighten its color and improve its odor. By exposure in shallow tanks its gravity is increased and fire-test lowered, and the peculiar fluorescence destroyed, or, technically speaking, it is "debloomed;" it is also rendered more brilliant in appearance. Attention to these details will secure a perfect lubricator for journals with high speed and light pressure.

Engine Oils.

For journals requiring a lower speed and a heavier pressure than the ordinary spindle, an oil of greater gravity than the usual spindle oil is required. An oil for this purpose is secured by altering the run of the still between the last two products, and by increasing the percentage of the yield of No. 2 oil, and consequently lowering the percentage yield of No. 3. By this modification, a very dense oil of 21° or 20° B. may be had with a proportionate increase in viscosity, and with a higher fire-test. A very superior engine oil, high in gravity and perfectly inodorous, may be made by taking the expressed oil, say of 30° B., placing the same in a perfectly clean still, and reducing it, by the aid of injected superheated steam, to the required gravity; by this process every particle of empyreumatic odor is removed. After the reduction has taken place it is removed to the bleacher, where it is kept warm by steam-pipes until every particle of water has subsided and the oil has become quite light. A very superior engine oil, suitable also for heavy machinery generally, is

also made by passing a reduced oil (*i. e.*, an oil made from crude oil by reduction in a still) through bone-black. Of course, such an oil will not have the cold-test of the class of oils just described. It has, however, a higher fire-test and greater viscosity.

The fire-test of the spindle oils is regulated at the still by an observation of the pyrometer at the time "the run of the still" is changed. The gravity generally will be found to increase with an elevation of the fire-test. The cold-test will depend entirely upon the completeness of the removal of the crystalline paraffine, and the care with which this part of the process is performed. If the freezing machine is inadequate or imperfect, or the process of expression carelessly done, the product is considerably lessened in value by a change in the cold-test.

Neutral Oils

Are refined paraffine oils varying in gravity from 32° B. to 38° B. For the purpose for which these oils are employed, it is especially necessary that they be thoroughly deodorized. They are largely used for the purpose of mixing with animal or vegetable oils. It is said that a mixture of 95 per cent. of a good neutral oil of the right gravity, and 5 per cent. of sperm oil has been sold for pure sperm. Ordinary inspection, as to odor and general appearance, would fail to detect the adulteration. Having been subjected to the usual refrigerating process for the extraction of crystalline paraffine, they will stand a cold-test from 20°

to 25°, and having been passed through the bone-black cylinders, they are very free from odor and have but little color. They are usually exposed for a few days in open shallow tanks for the purpose of removing the fluorescence of petroleum oils, the presence of which would quickly expose the adulteration with other oils. Unmixed with heavier oils, they are too light in body (especially the lighter varieties) to be employed as spindle or machinery oils, but when mixed with such oils in proper proportions they form admirable lubricating compounds for general purposes when very high speed is not required. Their comparatively low fire-test, also, would render them unsafe either as cylinder oils, or, in confined situations, as spindle oils, when an inflammable vapor would be dangerous. The fire-test of these neutral oils varies from 300° to 350°.

Mixed Lubricating Compounds.

Under this head may be noticed a variety of mixtures, both liquid and semi-liquid, which are used as lubricants. Every manufacturer or dealer has a special formula closely withheld from the public. Attractive names are given to these and superior qualities are claimed. The rigid tests to which these are subjected often dissipate this supposed superiority, and the best manufacturers have learned that honesty is the best policy, and frankly place upon the label of the sample bottle, the name of the oil, the purpose for which it is to be employed, its density, its fire-test, its viscosity. When these data are furnished the intelligent

consumer has the whole story and will not be disappointed in the results. Mineral oils are mixed in all proportions with sperm oil, whale oil, lard oil, neat's-foot oil, cotton-seed oil, rosin oil, castor oil, and indeed with every kind of oil used as a lubricant. The proportions between the various grades of mineral oils, and the different kinds of other oils, are as varied as the tastes of the dealers and the wants of their customers. Given, a specific purpose for which the lubricant is desired, the pressure upon the journals, their size and speed, and other circumstances attending its application, and it is by no means difficult to formulate a compound exactly adapted to the purpose. Besides the oils mentioned above, a number of solids are frequently mixed with mineral oils. Plumbago in a finely powdered state is largely used, and when the combination is properly made it is said to form a splendid "grease" for car-wheels, and for heavy machinery. It is said that the Johnson Graphite Oil Company prepares a mixture by which a car-wheel has made 13,000 miles of travel with one application. A very superior oil, known as "Galena" oil, is made by combining heavy, lubricating, natural oil with lead-soap. This compound is said to possess extraordinary tenacity and endurance.

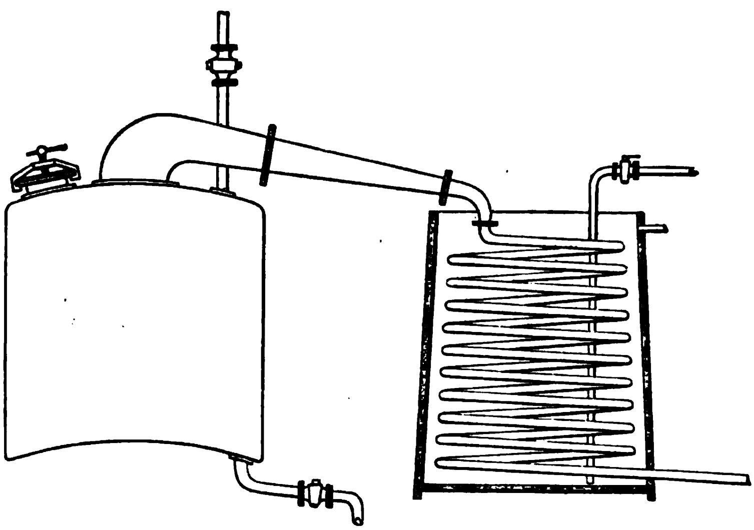
Tallow is also mixed with heavy paraffine oils for use in cylinders.

Manufacture of Photogen from Baku Naphtha.

The two principal operations in the manufacture of photogen are, the fractional distillation of the crude oil, and

the chemical refining of the distillate. The distillation is carried on in riveted boilers of from 8000 to 80,000 lbs. capacity, the small ones being invariably vertical (Fig. 89), and the large ones almost always horizontal. The cooling

Fig. 89.



apparatus is constructed either of cast-iron pipes or drawn tubes. The spiral form is the one most generally employed, only a few factories using the more advantageous coolers of straight pipes.

Distillation.

For distillation the boiler is filled three-quarters full with crude oil, and a brisk fire under the boiler kept up until the helmet commences to get hot. The fire is then

slackened and kept so until a pounding noise is plainly heard in the boiler. This is caused by the water contained in the naphtha becoming detached, in the form of steam-bubbles, from the bottom of the boiler. This noise becomes sometimes very deafening, and heavy blows which shake the boiler and surrounding brickwork are frequently experienced. This phenomenon, which might alarm an inexperienced person, is entirely free from danger. It is due to the large drops of water which are formed by the condensation of the aqueous vapor in the not thoroughly heated helmet and on the sides of the boiler, running back into the boiler and becoming immediately converted into steam on coming in contact with the hot bottom.

As water is heavier than the naphtha, and therefore collects on the bottom of the boiler, and the aqueous vapor formed must penetrate the entire mass of naphtha, a large quantity of water mixed with the latter will exert a very disturbing influence upon the quiet progress of distillation. The steam, which is generated in large quantities, flings the naphtha up and makes it foam so violently as to force it through the helmet into the cooler. This, to be sure, occurs but seldom, and can, as a rule, be avoided by correct firing in the beginning of the operation. Long experience has established the fact that the distillation of Baku naphtha is most readily accomplished by working it at a less specific gravity than 0.880. As crude naphtha of from 0.900 and higher specific gravity will run over, even if the boiler be only half filled, it must be freed from water before it

is pumped into the boiler. This is done by long-continued heating by steam in shallow double-walled pans.

As soon as the above-mentioned noise in the boiler commences to be heard, the first drops of the distillate make their appearance at the end of the discharge pipe of the cooler. They soon come more frequently and then form a continuous, gradually-increasing stream, which, when distillation is in full blast, becomes so large as to reach, with a large boiler, a product of from 2000 to 2400 lbs. per hour. In Russia there is a tax on the manufacture of photogen. In introducing it, the government assumed that each distillation would require one day, and the tax was levied accordingly, and must be paid in advance for every six working days. The manufacturers, in order to derive as much benefit as possible under this law, hasten the distilling process so as to make 25 to 30 distillations with each boiler during the six working days, without taking into consideration that a much better oil could be produced with a less violent distillation.

As the distillates passing over first have the lowest boiling points and the last the highest, with a gradual rise between the first and the last, the fire must be regulated accordingly and increased in the same degree as distillation progresses. The specific gravities and flashing points of the products of distillation rise in the same proportion as the boiling points.

The following table exhibits this relationship :—

Distillation temperature. Degrees.		Specific gravity at 14° R. (17.5° C.)	Flashing point in degrees.	
C.	F.		C.	F.
75	167	0.725	...	...
88	190.4	0.737	...	...
100	212	0.750	...	...
113	235.4	0.756	...	...
125	257	0.767	21	69.8
138	280.4	0.776	28	82.4
150	302	0.790	37	98.6
163	325.4	0.800	40	104
175	347	0.810	46	114.8
188	370	0.819	56	132.8
200	392	0.826	72	161.6
213	415.4	0.828	78	172.4
225	437	0.834	83	181.4
238	460.4	0.843	90	194
250	482	0.850	98	208.4

We do not mean to be understood to say that the first distillates make their appearance at 75° C. (167° F.). Products of 0.630 specific gravity pass over at 50° C. (122° F.), but as there is very little demand for this light oil, comprising benzene, gasolene, etc., it is in most instances allowed to run into the sea.

To prepare photogen with a flashing point of about 35° C. (95° F.) we are obliged to use the portions of the entire distillate between the limits of 0.770 and 0.850 specific gravity. All distillates below 0.770 and above 0.850 are almost entirely worthless for the fabrication of photogen, as the first, on account of their low flashing point, would be absolutely dangerous, and the latter would make the product too heavy to be raised in sufficient quantity by the wick of a lamp.

We would here mention two examples: (1) The mixture

of distillates of 0.710 to 0.850 from boilers with a charge of 40,000 pounds gave, with a forced progress of distillation, photogen with a flashing point at 34.5° C. (94.1° F.). (2) The flashing point of another mixture of 0.800 to 0.845, obtained at a slower progress of distillation, was 47° C. (116.6° F.). The yield of the first variety of photogen was 32 per cent., and of the second 28 per cent.

When the distillate has attained the highest specific gravity considered useful, distillation is considered finished. The fire is extinguished and the residuum remaining in the boiler may be allowed to run off, and the boiler be filled for another distillation.

The discharge of the residuum causes many difficulties and considerable loss of time, as even two or three hours after distillation is finished, it is still so hot that the vapors developed from it may, when mixed with the air, spontaneously ignite. To avoid this danger, one should wait at least six or eight hours before allowing the residuum to run into the bricked reservoirs below ground. But as time is of the utmost value in the Baku factories, the following plan has been adopted by which the residuum can be discharged in an hour after distillation is finished.

Immediately in front of the large reservoir for the residuum, which should of course be located as far as possible from the factory buildings, is a bricked pit several feet wide and deep, over which is placed a suitable vessel filled with water. The pipe, through which the residuum is conducted from the factory, ends in the pit, and a thin stream of water is allowed to fall down exactly upon the spot

where the residuum is discharged, so as to mingle with it. The water on coming in contact with the hot residuum is immediately converted into steam, which mixes with and envelops the vapors of the residuum, and thus protects them from ignition. The residuum is then discharged into the reservoir. But, independent of the fact that the thick vapor which is formed covers the surrounding country for a great distance like a dense fog, and has a disagreeable and irritating effect upon the lungs and eyes, this process is scarcely a safeguard against fire. In fact the conflagrations which so frequently occur among the Baku factories are largely caused by ignitions during this work. The arrangement adopted by the Nobel Bros. in their factory is much better. Here the residuum, before entering the reservoir, passes through a cooler of straight pipes placed in front of the reservoir. By having the cooler of a suitable size and providing a sufficient quantity of water, the residue can be cooled down so far as to develop no more vapors, thus making ignition impossible.

When distillation is carried on so far as to exhaust all the products of distillation which the naphtha can yield, a porous coke remains in the boiler, which is changed into a brittle or soft pitch, or a more or less thickly-fluid liquid by a decrease of the quantity of products distilled off. The residues obtained in the ordinary distillation of photogen are quite thinly-fluid, of a black-brown color, but without the green lustre of naphtha; they have a slight odor and a specific gravity of from 0.900 to 0.908, according to

whether light or heavy naphtha has been used, or the degree to which distillation has been carried.

The forced process of distillation, especially with large boilers, has the disadvantage that with the distillates intended for photogen, a considerable portion of products with a higher specific gravity than 0.850 passes over, which notably injures the quality of the photogen. To prevent this, small air coolers, called separators or dephlegmators, generally of a cylindrical form, are placed between the boiler and the cooler.

The boiling point of these heavy oils is so high that they become condensed by the slight cooling-off which the vapors suffer in passing from the boiler through the separator. They run off through a pipe in the bottom of the apparatus, and are either conducted back into the boiler, or into a special reservoir. From the separator, the photogen vapors, freed from the heavy distillates, pass into the cooler. The discharge pipe for the heavy oils is bent in the form of a U, which prevents the escape of non-condensed vapors.

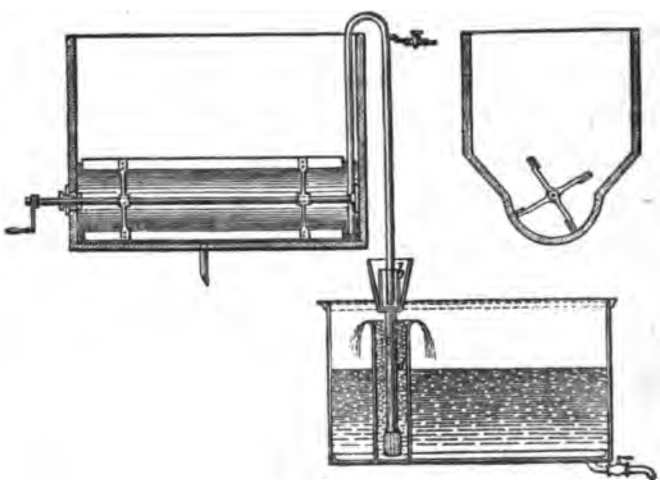
Chemical Purification of the Distillate.

In refining the crude photogen, the objective point is to mix it as intimately as possible, first with sulphuric acid and then with soda-ley, and to maintain this mixture for some time. But as the acid, as well as the ley, is considerably heavier than the photogen, and consequently has the tendency of settling on the bottom of the mixing vessels,

the latter must be so constructed as to render this impossible. Several kinds of mixing machines have been constructed for this purpose, which may be divided into two classes, namely, mechanical mixers and air mixers. In the first, the liquids are mixed by any desired mechanism, while in the latter, the mixture is effected by forcing through them a current of air from an air-pump.

Fig. 40 shows a mixing apparatus worked by hand. The upper mixer, which is of wood lined with lead, and

Fig. 40.



provided with a stirring apparatus, serves for treating the crude photogen with sulphuric acid; the lower one of iron, for the mixture with soda-ley, is self-acting. After mixing the photogen with acid and removing the residue of acid from the apparatus, the lead siphon, *a*, placed in the lead vessel *b*, which is previously filled with photogen,

is put in operation. The funnel-shaped pipe *c*, the lower end of which is closed, is provided, for about two or three inches from the top, with numerous small holes through which the acidulated photogen enters the soda-ley in the cylinder, *d*, and after passing through it in a finely-divided state, rises up and runs off over the edge of the cylinder.

Figs. 41 and 42 are mixing contrivances, driven by a

Fig. 41.

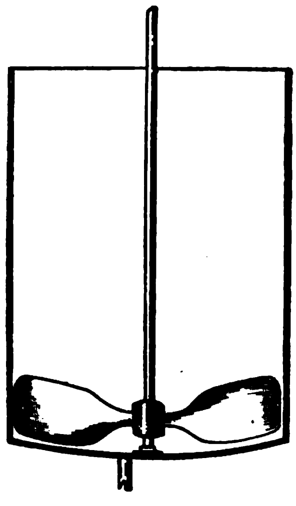
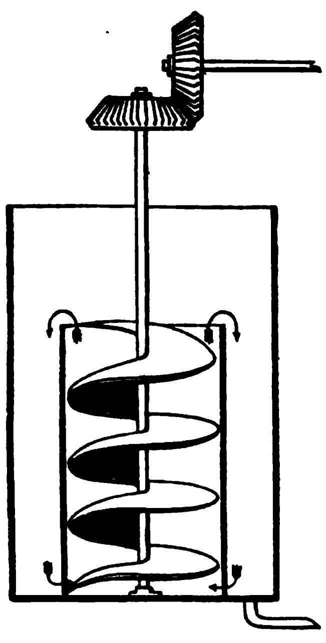


Fig. 42.



machine, which can be highly recommended. After the apparatus is filled with crude photogen, the machine is set in motion and the acid or ley allowed to run into the inner cylinder in which revolves an Archimedean screw. The screw lifts the mixture of photogen and acid, or of

photogen and ley to the upper end, where it runs over into the outer cylinders, and, after sinking down, is again sucked into the inner cylinder through holes in the bottom, the circulation, as indicated by the arrows in Fig. 42, being continued uninterruptedly as long as the machine works.

Air mixers, which are very simple in construction, are more suitable for large operations, as, for instance, in the factory of the Nobel Bros., where 480,000 lbs. of crude photogen are subjected to refining at one time. They consist of the body of the mixer lined with lead and an air pipe carried to the bottom. In an apparatus with a large bottom surface, the air-pipe is distributed as a pipe system, in the form of a star or spiral, provided with numerous small holes through which the compressed air escapes.

The crude photogen to be refined is brought into the mixing apparatus, and, after drawing off the water, which may have accidentally got into the apparatus together with the photogen, the cock of the air pipe is opened. As soon as the photogen is thoroughly agitated, the sulphuric acid is admitted in a thin stream from a lead vessel standing over the mixer. For refining 4000 lbs. of crude photogen 35 to 40 lbs. of sulphuric acid of 66° B. are required. Shortly after adding the acid, the color of the photogen changes to a red, the penetrating odor of sulphurous acid making its appearance at the same time. This is evidence that the sulphuric acid exerts an oxidizing effect, not upon the hydro-carbons which compose the photogen, but upon other products of distillation, which are partly of an acid character and to be considered as impurities. After the

apparatus has been working about half an hour, a sample is taken and tested, by allowing it to stand for a few minutes, then carefully pouring off the photogen from the sediment into a glass cylinder, adding a few drops of soda-ley and shaking thoroughly. The photogen should assume a milky appearance, and its color should be pure white, without the slightest trace of a yellowish tint. If such is the case the mixing process may be interrupted. If, however, the photogen shows a yellowish tint, more acid, about one-third the quantity first used, must be added, and the mixing continued. Should the yellowish tint not be removed from a fresh sample, the operation is interrupted, and, after removing the old acid from the apparatus, commenced anew.

Such irregularities in the refining with acid occur, however, very seldom, and, as a rule, only when photogen is brought into the mixer still warm. Yellow photogen, even of a darker color than the original, is also obtained if the sulphuric acid used is not entirely free from nitric acid. It is, therefore, advisable in buying sulphuric acid to test it as to its purity.

After the mixing operation is interrupted and the acid has settled, good photogen should be perfectly pure and clear and of a rose color. The acid residuum forms a black viscous liquid with unimpaired acid properties. After resting for some time the acid photogen is brought into the ley-mixer and treated with soda-ley of from 30° to 33° B., about 20 to 25 pounds of which are required for 4000 pounds of photogen.

By the action of the soda-ley the acid character of the photogen, which it has acquired by the treatment with sulphuric acid, is neutralized, and admixtures, which on account of their chemical nature were not destroyed by the sulphuric acid, are fixed.

On mixing the photogen with the ley, a milky turbidity sets in immediately, which, by continuing the mixing for about ten or fifteen minutes, balls together and forms white flakes, which float in the now colorless and limpid photogen. After the appearance of this reaction the mixing operation is interrupted. After allowing the residue of the ley to settle, it is drawn off, and the photogen brought into pans to be washed.

After the treatment with ley the photogen cannot be considered finished, no matter how thoroughly it may have been cleansed. If such photogen be burnt in a lamp the wick becomes hard and covered with a crust which diminishes the light. This is caused by a small portion of soda from the ley passing into the photogen, which, in burning, converts the carbonic acid of the products of combustion into sodium carbonate. To remove this defect, the photogen must be washed, which is best done first with a small quantity of diluted acid (6° to 8° B.) and finally with pure water.

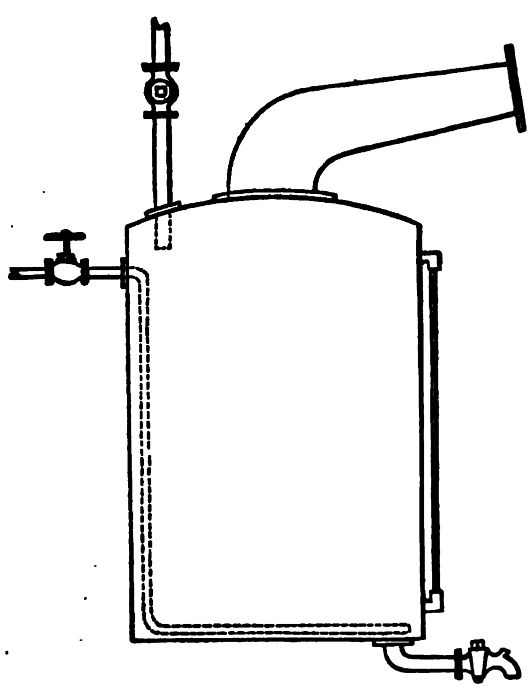
Utilization of the light Distillates.

As previously mentioned, the light oils evaporated during the first distillation are allowed in most instances to run into the sea, but lately certain refiners have commenced

to work them into gasolene and benzene, and, though the market for these products in Russia is limited, they yield a reasonable profit. For this purpose the light oils are subjected to a purification with sulphuric acid and soda-ley and a subsequent rectification.

The rectification is carried on in iron stills with a helmet turned slightly upwards (Fig. 43), so that the non-distilled

Fig. 48.



parts, carried away with the vapor, are mechanically re-conducted into the still. After rectification is finished, a product amounting to about forty per cent. of the material

used, and of 0.812 to 0.815 specific gravity, remains in the still. This is added to the crude photogen to increase the yield of refined oil.

Manufacture of Lubricating Oil from Baku Naphtha.

The residues from the distillation of the crude naphtha are utilized for the manufacture of lubricating oil which, like the distillation of photogen, is divided into two principal operations, viz., fractional distillation of the residues, and chemical purification of the distillates.

The principal difference between the manufacture of photogen and lubricating oil consists in the following: The distillation of the residues cannot be carried on with fire alone, the use of superheated steam and employment of separators or dephlegmators being absolutely necessary for the production of a good article. Superheated steam is absolutely required, as the vapors formed in this distillation are so heavy that they rise with great difficulty from the surface of the boiling fluid in order to pass through the helmet into the cooler, and would be decomposed by remaining too long in the boiler, in which a very high degree of temperature (250° to 300° C., 482° to 572° F.) prevails. In carrying on the distillation without superheated steam, the result would be, not lubricating oil, but ill-smelling products of decomposition with scarcely any lubricating power. But superheated steam introduced into the boiling naphtha-residues quickly carries off the oil vapors, and, by becoming intimately mixed with them and enveloping

even the smallest particles, protects them from the destructive influence of the hot metallic sides of the boiler and helmet. The steam must be superheated so as not to cool off the boiling fluid, the boiling point of which is considerably higher than the temperature of ordinary steam, even at a very high pressure. As regards the chemical purification of the crude oil, the process is the same as for photogen, except that a larger quantity of the same chemicals is required.

Distillation.

Fig. 44 shows a complete distilling apparatus. *A* is the heater for superheating steam; *B*, the still; *C* and *D*, separators; *E*, the cooler; and *F*, the receiver. The superheated steam passes through the pipe *a*, into the boiler, where, as seen in Fig. 45, it must pass through four windings before it enters the contents of the still through small holes in the last three pipes. Through the pipes *b* and *c* (Fig. 44 *a*), the oils which have been condensed in the separators, pass into the receiver and from there into the collecting reservoir.

Of all heaters for superheating steam, we give the preference to that formed of straight pipes, with the connecting pieces placed outside the furnace. They produce the same effect as those of pipes bent in the most artistic manner, and have the advantage that a defective pipe can be removed with great ease and replaced by a new one. The joints outside the furnace can be easily protected from

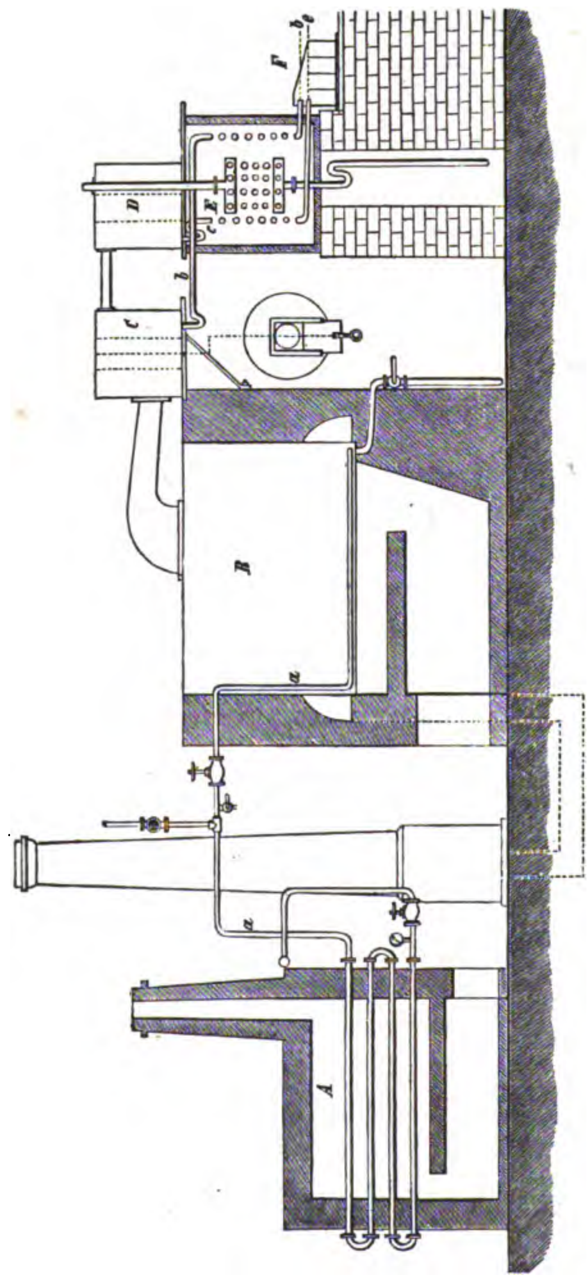


Fig. 44.

Fig 44 a.

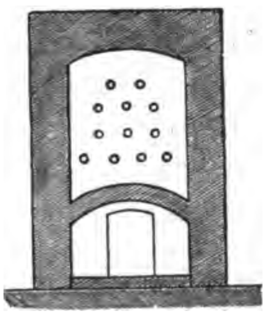
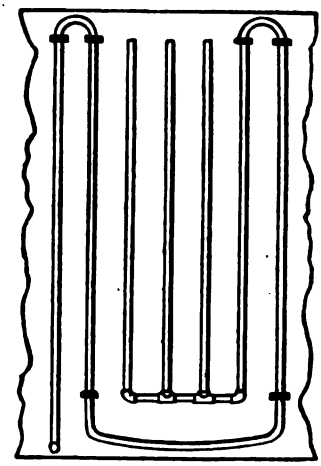


Fig. 45.



cooling off. The last pipe of the superheater, which is connected with the conduit leading to the still, is provided with a branch to allow the steam to escape into the open air while it is being heated, and also with a cock for the discharge of condensed water and for the determination of the temperature of the superheated steam. For the distillation of naphtha residues, it is necessary to superheat the steam to three different degrees, namely, approximately to 150°, 240°, and 300° C. (302°, 464°, and 572° F.) The first degree is recognized by the hand, which, when passed through the steam escaping from the test-cock, should remain perfectly dry. Steam superheated to the second degree has no longer the dense, white, nebulous appearance of ordinary steam, but is bluish and thin, like the smoke of a good cigar. When the third degree is reached, the steam escaping from the test-cock is not visible, though the

ordinary whistling noise of escaping steam is heard. As it is very important not to superheat steam to above 300° C. (572° F.), and the steam itself furnishes no guide, the proper temperature is recognized when a piece of paper pressed with a stick against the pipe turns dark yellow. If it turns brown, or carbonizes, the temperature is too high. The above device of a testing cock for determining the temperature of the superheated steam is preferable to a pyrometer, which is very expensive, and at the same time so unreliable that after having been used for a short time it is apt to lead one astray.

The distillation is carried on in the following manner: After the still is heated so far that the first drops of distillate make their appearance on the end of the discharge pipe of the cooler, the valve on the pipe system leading from the steam boilers, which are worked with a pressure of about 40 pounds, is opened and sufficient steam passed through the superheater to cause the manometer to show a pressure of 15 pounds. In doing this, the valve in front of the still must, of course, be closed, and the previously mentioned branch pipe on the last pipe of the superheater, and the testing cock, be opened. When the steam is superheated to the first degree, the valve in front of the still is opened one or two turns, and after a few minutes the branch pipe is closed one or two turns, and the test-cock shut off. When the first effect of the steam becomes apparent, *i. e.*, when the condensed water and a somewhat greater quantity of distillate run off from the cooler, the first valve is again opened and the second closed one

turn, this opening and closing of the two valves being continued until a vigorous, but quiet, progress of distillation is established, after which the superheating of the steam and brisk heating of the still are carried on as uniformly as possible. The proper proportion of steam is of as much importance to the success of the distillation as its temperature. At the commencement of distillation, when only light products pass over, so much steam should be used, that, when a sample of the distillate is examined in a glass, the condensed water should be to the oil in the proportion of 1 : 2, but when the oils begin to pass over the proportion should be 1 : 1.

The first distillates show a specific gravity of 0.850 to 0.860, according to whether light or heavy residues are used. They are of a light-straw color, and, like all distillates obtained with superheated steam, turbid. With a brisk fire under the still, the specific gravity rises rapidly, so that in a few hours it is 0.885. At this stage, the second period of distillation commences, to the end of which (*i. e.* until the specific gravity of the distillate is 0.905) the steam must be heated to 240° C. (464° F.) and its pressure increased from 15 to 25 pounds, which is effected by opening the valve in the steam conduit wider. The distillate which runs off, is conducted into a separate division of the receiver and thence into the proper collecting reservoir. The mixture of all the distillates of this period has, generally, a specific gravity of 0.895 to 0.897 and is of a lemon color.

During the third and last period, which commences

with a specific gravity of the distillate of 0.905, the pressure of the steam is increased to from 30 to 35 pounds, and its temperature to 300° C. (572° F.). Direct firing is now so managed as simply to assist the steam, care being had not to allow the temperature of the latter to get above 300° C. (572° F.). Distillation may be considered finished when the distillate has acquired a dark brownish-red color, or, when, upon the surface of a sample cooled off to about 6° or 8° C. (42.8° to 46.4° F.) a film is formed, which indicates the commencement of paraffine distillation. Though Baku naphtha contains remarkably little paraffine, its mixture with the lubricating oil must be avoided.

As will be seen from Fig. 44, there are three discharge pipes on the water reservoir of the cooler. The pipes *a* and *b* which branch off from the two separators, discharge odorless, yellow, to orange-colored oils without any admixture of condensed water, which last, with a small quantity of badly-smelling oleaginous products, runs off through the pipe *c*. In the distillation of naphtha residues, no matter how carefully conducted, a partial decomposition of the oils can scarcely be avoided, though it can, of course, be reduced to a minimum. The boiling point of the undecomposed oils, however, is so high, that the slight cooling off, which the oil vapors experience in passing the separators, is sufficient for their condensation, while the vapor-like products of decomposition and the steam used in the distillation pass through both separators and are finally condensed in the water cooler. From the first separator, which, being nearest to the still, has the highest temperature, the heaviest

oils with the highest boiling points are discharged, and, from the second separator, a somewhat lighter variety, the difference in their specific gravities being 0.002 to 0.004.

Chemical Purification of the Lubricating Oil.

The oil is refined either with or without rectifying distillation. According to the first method, the mixture of the light and heavy oils is treated with sulphuric acid, neutralized with air-slaked lime, and finally rectified, whereby the different grades of oil are separated from each other. In refining without a second distillation, each grade of oil is separately treated, first with sulphuric acid and next with soda-ley, and finally washed twice or three times with hot water.

The quantity of sulphuric acid, as well as that of soda-ley, required for refining, varies from 4 to 12 per cent. according to whether light, medium, or very heavy oils are to be worked. Before refining, the crude oil must be entirely dephlegmated, which is best done by heating it to about 60° or 70° C. (140° to 158° F.) by steam, and allowing it to rest for some time. The same apparatus described for refining photogen may be used, with the exception that the ley-mixer should be provided with an arrangement for heating the oil by steam. The temperature of the crude oil, when subjected to treatment with sulphuric acid, should not be higher than 30° C. (86° F.). The acid is gradually added to the strongly-agitated oil, and the mixing process kept up for at least 1½ hours. The oil assumes a dark

color, which, however, when examined in a thin layer, must not be brown, but red. After mixing, the acid separates together with other impurities, in a thick, viscous layer, which, after standing for some time, frequently forms solid masses.

After resting, the acidulated oil is mixed with soda-ley of 33° B. When this operation is finished, the oil is heated to from 35° to 40° C. (95° to 104° F.), and allowed to rest. The sediment is then removed from the apparatus, the clear oil heated to 60° C. (140° F.), and washed with water heated to the same temperature. The oil is then conducted into the settling reservoir, where it remains at the same temperature until it is entirely clear.

CHAPTER X.

OIL TESTS.

PETROLEUM is subjected to the following tests to ascertain—

I. By the application of heat, what is termed its "fire-test," by which two points are determined, viz: "the flashing point" and the "burning point."
II. Its specific gravity.
III. Its "viscosity;" applied only to lubricating oils.
IV. Its composition and its freedom from admixture with other oils or foreign substances.
V. Its natural composition by actual assay.
VI. The degree of cold it will stand without "thickening" or depositing crystalline paraffine.

I.—THE FIRE-TEST.

The frequent dangerous and even fatal accidents which attended the introduction of petroleum oils early necessitated the employment of some tests to distinguish between those which were safe and those which were unsafe. The dangerous element in "illuminating oils" is the volatile benzene, which inflames at quite low temperatures. A very small percentage of high-gravity benzene will render an illuminating oil unsafe. To detect the presence of this

inflammable element a number of machines have been devised, concerning which, and their applicability to the purpose designed, a great difference of opinion exists. Much of this needless controversy would cease could there be established in this country, as there has been already in several foreign countries, a legalized standard method. In Holland, the Parrish naphthometer is employed. In England and Canada, Professor Abel's instrument. In France, the apparatus of Salleron-Urbain. In the United States, Tagliabue's instruments (both the open and closed) are largely employed. The New York Petroleum Association, after a careful examination of all the instruments employed for this purpose, adopted the Saybolt electric tester. Another electric apparatus has been devised by Engler. It may readily be conceived, that, with such a variety of instruments each with a different method of manipulation, there should be frequent controversies respecting the "fire-tests" of shipments of oil. In the United States the practice is, generally, to submit the oil intended for export to the test of that country to which the oil is sent. Thus, in the large refineries engaged in the export trade, there will be found in constant use almost every variety of "tester" of acknowledged importance. For the home trade, Tagliabue's instruments, or the Saybolt tester, will be found sufficient.

The earliest and simplest mode of testing the inflammability of illuminating oils was to place a tea-cup, filled about three-fourths with the oil to be tested, in a suitable vessel of boiling water. A thermometer was placed in the

oil, and held with one hand, while the other was left free to apply a lighted taper from time to time, the thermometer being watched in the meanwhile. The point at which the oil fired was the "fire-test" of the particular sample. Of course this test was a rude one and the results were variable even in the hands of the same operator; but, insufficient as this apparatus was, it contained the germ of every subsequent improvement.

The varying results referred to are caused by the following circumstances:—

1. The difference in the time employed in heating the sample of oil. It has been found by actual experiment that a sample of oil will vary as much as 13 degrees, according to whether 15 minutes or 30 minutes are employed in raising it to the flashing point.

2. The protection of the tester from draughts of air. That this should cause a serious discrepancy between different experiments upon the same oil, must be obvious.

3. The size and nature of the test flame.

4. The nearness of the test flame to the surface.

5. The duration and frequency of the application of the test flame.

Now, the various improvements which have been made in oil testers, have had for their object the elimination of all these sources of error which have been pointed out. For instance, Tagliabue's open testers have been largely supplanted by his improved closed apparatus. The size of the flame and its distance from the surface of the oil have been completely regulated by the Saybolt

electric instrument, while the other irregularities mentioned, have been avoided by regulations concerning the size of the oil-cup, its surrounding water-bath, and by specific directions as to heating this, by employing a thermometer in the water-bath as well as in the oil-cup. Yet, with all these precautions, different operators will obtain different results with the same instruments; notwithstanding this, however, the difference has been reduced to a minimum, and the slight variations are practically of no account, and the certificate of an authorized inspector is received as final.

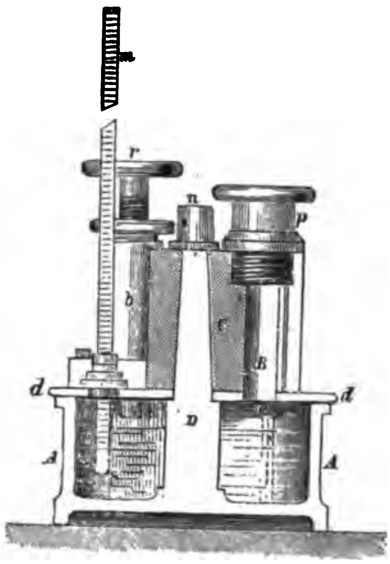
The following description of the various forms of apparatus for determining the flashing and burning points, together with the diagrams illustrating their use, is taken from the reports of the U. S. Census Bureau for 1880, made by Professor S. F. Peckham.

The Salleron-Urbain Apparatus (employed in France).

This is used for determining the expansion of the vapor of petroleum. It consists of a copper vessel, *A*, Fig. 46, in which is fixed the conical pillar *D*, and which is covered by the plate *d d*, fitting on its upper edge. *C* is a movable plate turning on the pillar *D*, and held in place by the screw *n*. In this movable plate is the cylindrical chamber *B*, closed at the top by the screw-plug *p*, while its lower opening can be placed in communication with the vessel *A*, by means of the opening *o*, or, by turning the plate *c*, it can be sealed by the upper surface of *d*. There are also in the plate *d*, a thermometer, a graduated tube

m, 35 cm. long, and the regulating apparatus *l*, which consists of the screw *r*, so arranged that by raising or lowering it, the water level in *m* is made to stand at zero.

Fig. 46.



Salleron-Urbain Tester.

Fifty cubic centimetres of water are put in the vessel *A*. *B* is nearly filled with the petroleum to be tested, the screw *p*, replaced, and the whole placed in warm water until the temperature has become constant. The water level in *m*, is placed at zero, and then the plate *C* is moved until the opening of *B* comes over the opening *o*. The petroleum spreads upon the surface of the water in *A*, and by the expansion of its vapor causes the water to rise in the tube *m*, when its height is read. By a comparison of this number with the known expansion of the vapor of normal petro-

leum at a corresponding temperature, the combustibility of the oil is determined. For this purpose a table accompanies the apparatus which gives the obtained vapor-expansion of normal petroleum in *m*, for different temperatures sought.

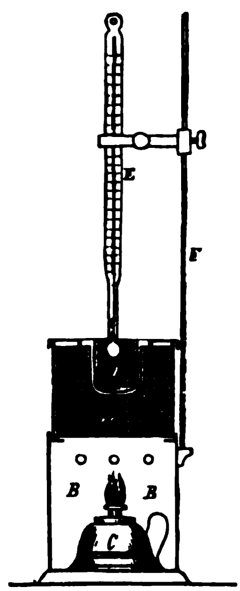
So far as we have been able to examine the records of the results obtained from this form of tester, it appears to be poorly adapted to the requirements of the American refiner.

Tagliabue's Open Tester.

This apparatus (Fig. 47) was employed in the official testing of petroleum in this country until 1879, and with immaterial changes, and under various names, it is still used in Germany. It consists of a brass water-bath *A*, upon the stand *B*, heated by the lamp *C*. *D* is the glass petroleum-holder, in which is immersed the thermometer, *E*. The bath is nearly filled with cold water, allowing for the displacement by the oil-holder. *D* is filled to the top with the petroleum to be tested (care being taken not to wet the rim), the thermometer placed in position and the lamp lighted. The heating should be gradual, and if necessary the lamp be occasionally removed. When the oil has reached the temperature at which the operator wishes to begin testing, a small flame, either from a wooden splinter or a gas jet, is slowly and carefully passed over the petroleum, about half an inch from the surface. If no flashing takes place, this is repeated as the temperature rises until

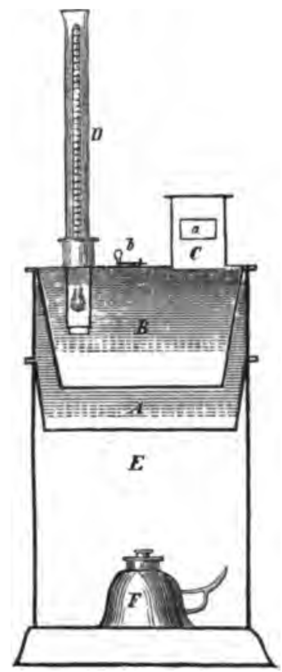
the flashing point is reached. During the testing, the apparatus should be protected from draughts of air.

Fig. 47.



Tagliabue's Open Tester.

Fig. 48.



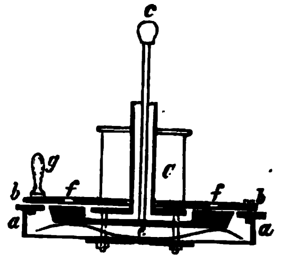
Tagliabue's Closed Tester.

Tagliabue's Closed Tester.

The Tagliabue closed tester (Fig. 48) consists of the water-bath *A*, and the petroleum-holder *B*, both of brass. The latter is provided with a cover, upon which are fixed the hood *C*, containing a rectangular opening *a*, the sliding bar *b*, for opening or closing the aperture beneath it, and lastly, the thermometer *D*. There is also an improved form of this tester differing from the first in the arrangement of the cover, which is shown in Fig. 49.

In this, *a a* is the cover, with openings under the movable bar *b b*, by which they are closed; *f f*, are small open-

Fig. 49.



Tagliabue's Closed Tester.

ings in *b b*, closed by the piece *e*, held up by the spring beneath it. By pressing upon the knob *c*, the apertures *f f*, are opened, and the bar *b b* can be moved by the handle *g*.

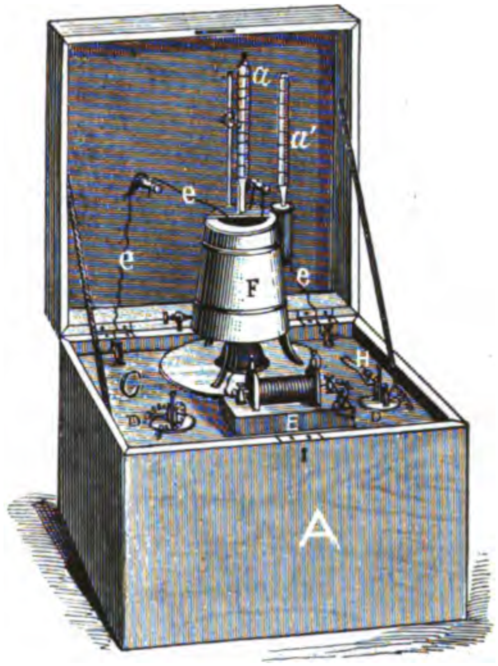
In using this apparatus, the water-bath as well as the oil-holder are filled and the bath gradually heated by the spirit-lamp. When the thermometer reaches a definite temperature, a small flame is introduced through the opening *a*, into the hood *C*; and at the same time the bar *b*, in Fig. 48, is moved to one side, or, as represented in Fig. 49, the knob *e*, is pressed down, in order to establish communication with the air by openings *b*, or *f f*. The testing is repeated as the temperature rises, until the flashing point is reached.

The Saybolt Electric Tester.

This apparatus was adopted by the Produce Exchange of New York in 1879, in testing refined petroleum. It resembles the open tester of Tagliabue, differing only in

use of the electric spark in place of the burning splinter. It is shown in Fig. 50, and consists of the copper water-bath *F*, containing the petroleum-holder, which, with the other parts of the apparatus, are placed on the tray *C*, and,

Fig. 50.



Saybolt's Tester.

for transportation, can be inclosed in the box *A*. *D D* are the covers of two battery elements. *H* is a current-breaker. *E*, an induction coil, and *e e*, the conducting wires for producing the spark over the surface of the petroleum; *a* is the thermometer of the oil-holder, and *a'* that of the water-bath. In using this apparatus, the bath is filled with

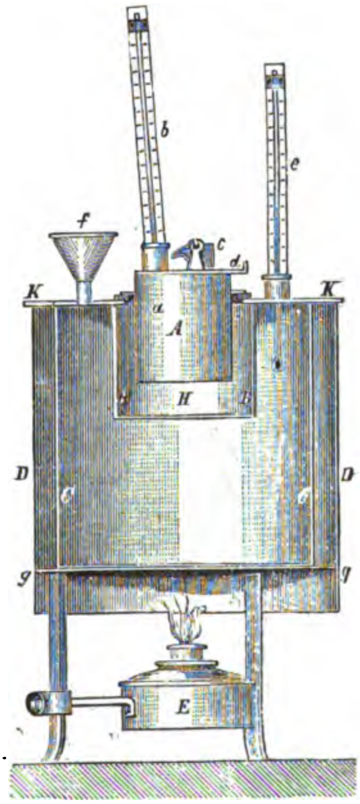
water, and heated to 100° F., after which the lamp is removed, the oil-cup, filled to within an eighth of an inch of the top with the petroleum to be tested, is placed in the bath, and the thermometer is immersed in the oil until the bulb is just covered. As the temperature of the oil is raised to 90° F., a spark is produced by the key *H*, and after replacing the lamp the operation is repeated every two or three degrees, until the flashing point is reached.

The Abel Tester.

The apparatus of Professor Abel, represented in Fig. 51, is employed in England in determining the flashing point of petroleum. It consists of the copper cylindrical vessel *D*, in which is the water-bath, composed of the two copper cylinders *B B* and *C C*, the latter resting on the ring *g g* and covered by the plate *K K*. *f* is a funnel for filling the water-bath, and *e* is the thermometer placed in it. The brass petroleum-holder *A*, rests in an ebony ring fixed in the plate *K*, and hangs in the air-filled space *H* of the water-bath. It is provided with a closely-fitting cover, through which passes the thermometer *b*, and upon which is placed the small oil-lamp *c*, movable upon the horizontal axis. There are also in the cover three rectangular openings, which can be opened and closed by the sliding bar *d*, by the movements of which the lamp is so tipped that its nose comes opposite to the opening in the middle of the cover. The oil-lamp can be replaced by a gas flame, which is much cleaner and was used in the experiments with this apparatus. The water-bath is filled and heated

to 54° C. *A* is then filled to the mark *a* with the petroleum to be tested, covered, and placed in the space *H*. The

Fig. 51.



Abel's Tester.

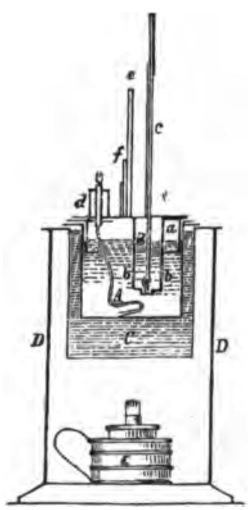
wick of the lamp is arranged to give a flame four mm. long. When the temperature by the thermometer *b*, has risen to 19° C., the tests are commenced and repeated every degree or two until the flashing point is reached. In testing very volatile oils, the air space *H* should be filled with

cold water, and, in the testing of oils of high flashing point, this water should be heated to about 50° C.

The Parrish Naphthometer.

This instrument is used chiefly in Holland, and differs from those already described, in that the inflammable mixture is carried out of the petroleum-holder to a stationary flame. *A* represents the tin oil-holder, *C* the water-bath,

Fig. 52.



Parrish's Naphthometer.

D the support, and *E* the lamp. The holder is provided with a projecting cover, in which is the cylinder *d*, having in its axis a small tube, with a wick running into the petroleum. *e* is a screw, against whose base rests the glass plate *f* for protecting the thermometer from the heat of the wick-flame, and, lastly, *B* is a chamber communicating with the

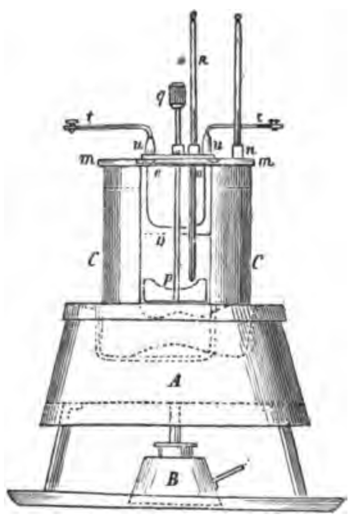
air in which are the openings *a* and *b*; the former, for the circulation of the air through the petroleum-holder, and the latter, to allow the passage of the oil from *B* into *A*. The thermometer *c* is placed in the vessel *B*. The bath is filled with cold water, and the oil-holder with the petroleum to be tested, to a point one cm. below the rim. The heating must be slow and is effected by the spirit-lamp, whose flame is only one to one and a half cm. high. The small wick in *d* is then lighted, care being taken that the flame is not more than six to seven mm. high. The heat of this flame produces a current of air, which, coming in through the opening *a*, spreads over the surface of the oil and passes out by the tube *d*, taking with it the vapors evolved from the heated oil. When the oil vapors are sufficient in amount to produce an inflammable mixture they are ignited by the flame in *d*, the flame being extinguished by the sudden motion of the air. At this moment the flashing temperature is read.

Engler's Tester.

The apparatus devised by Engler is of the closed form, to which is added an electric mechanism similar to that of the Saybolt tester. It is shown in Figs. 53 and 54. It consists of the copper water-bath *A*, heated by the spirit-lamp *B*. *C C* is a glass vessel for water, which has a filling mark etched upon it. *m m* is the cover, and *n* the thermometer. In the cover is the glass petroleum-vessel *D*, also provided with a filling mark, and to which is fitted the brass cover *o o*. The latter is shown in Fig. 54, in

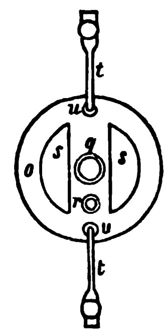
which will be noticed the following details: *s s* are two movable covers, *t t* the conducting wires insulated by the ebony rings *u u*, *r* the thermometer, and *q* the handle of the stirrer *p*, seen in Fig. 53. The conducting wires

Fig. 53.



Engler's Tester.

Fig. 54.



Engler's Tester.

terminate in platinum points in the vessel *D*, from one-half to two-thirds cm. above the surface of the oil, and at a distance of one mm. from each other. For the production of the electric spark, a chromate cell is used with an induction apparatus, which gives a spark at least two to three mm. long. The electric apparatus of the Saybolt tester answers very well. In using this tester, the baths *A* and *C* are filled with water, and *D* is filled to the mark with the oil to be tested. When the petroleum vessel is in place, the water in *C* should stand one cm.

below the rim. The wires are connected with the induction coil and the lamp lighted. As the temperature rises to the testing-point, the spark is passed every degree, care being taken that the spark continues from one-half to one second. After each passage of the spark the oil is gently agitated by the stirrer. The operation is continued in this way until an explosion occurs, by which the covers *s s* are thrown open.

In the hands of a careful manipulator, reliable results may be obtained by either of the above-described instruments. The difficulty has been that different results have been obtained by different operators in using the same tester. The cancellation of contracts, acrimonious differences, expensive lawsuits have all arisen, simply because legislation of a national or international character has been wanting to regulate so important a feature of a traffic amounting in the aggregate to millions of dollars.

The vast number of experiments which have been made to determine the accuracy of the different kinds of tests has at least pretty conclusively settled the question as to the superiority of the "closed" form of apparatus.

A very exhaustive report on this subject was made "to the Secretary of State for the Home Department" of England by Professor F. A. Abel, Chemist to the War Department, in which, having carefully considered the causes of the variable results obtained in testing the flashing point of different kinds of petroleum, he submitted a form of apparatus for adoption, together with specific directions for its use. This, which we have already described, is, we think,

exclusively employed in England and its colonies, and is also extensively used in this country. It is claimed, however, by those of large experience, that equally reliable results are obtainable by the Saybolt and Engler electrical testers.

There is considerable difference between the flashing points of samples of oil tested in the "open" and "closed" apparatus. In the open tester, first adopted and legalized in England, 100° F. was chosen as a safe point. In the Abel apparatus now in use, the same point is reached at 73°, a difference of 27°, which Professor Abel says "might without injustice to the trade be accepted as the difference between the results to be furnished by the new test and the present legal test; or, in other words, that 73° might with the new test be accepted as the equivalent for the present legal minimum flashing point of 100°."

There is also a difference of many degrees between the flashing point and the burning point of a given sample of oil. Oils differ greatly in this respect; a very small percentage of light benzene will greatly lower the flashing point; if the great body of the oil is of high test, there will be a large difference between these two tests; but, on the other hand, if the bulk of the oil be of a lower grade, the difference between the flashing and burning points may amount to only a few degrees. The following table prepared by Dr. C. B. White, of New Orleans, being the result of a number of experiments, illustrates the effect of varying quantities of benzene mixed with oil, in changing the flashing and burning points of the same:—

Oils.	Flashing point. Deg. F.	Burning point. Deg. F.
Oil alone	118	135
Mixed with 1 per cent. Benzene 65° B.	112	129
" 3 " " "	103	123
" 5 " " "	96	116
" 10 " " "	83	102
" 1 " " 72° B.	107	133
" 5 " " 72° B.	70	105

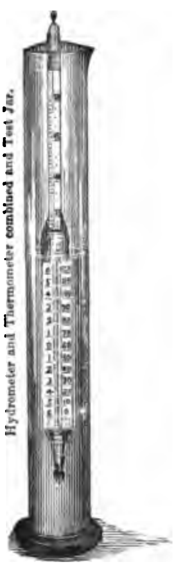
II.—The Specific Gravity of Petroleum

Is ascertained by the use of either one or the other of the instruments here described. Fig. 55 represents the ordinary hydrometer graduated according to the Baumé scale for liquids lighter than water. Fig. 56 represents the combined hydrometer and thermometer. Fig. 57 represents the vessel usually employed for holding the oil, and is known as the hydrometer jar. The only other instrument employed for this purpose is the one-thousand-grains bottle represented in Fig. 58. This bottle is filled, accurately up to the mark on the neck, with the oil to be tested. This instrument has been accurately gauged and marked to contain 1000 grains of distilled water at a temperature of 60° F. It is, therefore, necessary, before the oil is placed in this bottle, that it should be carefully brought to the same degree of temperature. After filling, the bottle and contents are weighed in a delicate balance, and the specific gravity thus determined. It is also designed, in the use of the hydrometer, that the oil should be of the same temperature (*i. e.* 60° F.), and, if it is either above or below this point, a certain correction must be made. In the earlier days of

the manufacture of petroleum, it was customary to allow a change of one degree of Baumé's hydrometer for every ten degrees of temperature. For example, a sample of oil testing 45° B. at 50° temperature, would be considered as

Fig. 55.

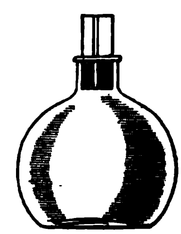
Fig. 56.



Hydrometer and Thermometer combined and Test Jar.

Fig. 57.

Fig. 58.



having a gravity of 46° B. at a temperature of 60°, or a gravity of 44° B. at 40° F. Much more accurate computations are now made, and elaborate tables accompany the case of Taliabue's delicate hydrometers which are graduated to a scale of degrees in tenths.

The following table will be found extremely useful in converting Baumé markings into true specific gravities. This table refers only to liquids lighter than water. There are similar tables for liquids heavier than water.

For Liquids Lighter than Water. (*Temp.* 60° *Fahr.*)

Baumé.	Specific gravity.	Baumé.	Specific gravity.	Baumé.	Specific gravity.
10	1.0000	37	0.8383	64	0.7216
11	0.9929	38	0.8333	65	0.7179
12	0.9859	39	0.8284	66	0.7142
13	0.9790	40	0.8235	67	0.7106
14	0.9722	41	0.8187	68	0.7070
15	0.9655	42	0.8139	69	0.7035
16	0.9589	43	0.8092	70	0.7000
17	0.9523	44	0.8045	71	0.6965
18	0.9459	45	0.8000	72	0.6930
19	0.9395	46	0.7954	73	0.6896
20	0.9333	47	0.7909	74	0.6863
21	0.9271	48	0.7865	75	0.6829
22	0.9210	49	0.7821	76	0.6796
23	0.9150	50	0.7777	77	0.6763
24	0.9090	51	0.7734	78	0.6730
25	0.9032	52	0.7692	79	0.6698
26	0.8974	53	0.7650	80	0.6666
27	0.8917	54	0.7608	81	0.6635
28	0.8860	55	0.7567	82	0.6604
29	0.8805	56	0.7526	83	0.6573
30	0.8750	57	0.7486	84	0.6542
31	0.8695	58	0 7446	85	0.6511
32	0.8641	59	0.7407	86	0.6481
33	0.8588	60	0.7368	87	0.6451
34	0.8536	61	0.7329	88	0.6422
35	0.8484	62	0.7290	89	0.6392
36	0.8433	63	0.7253	90	0.6363

III.—Viscosity.

This term very vaguely describes what has been supposed to be the most desirable quality of a lubricating oil. The word viscidity, a complete synonym, throws no further light upon its real meaning. While it bears an important relation to lubricating oils, it by no means follows that the most viscous oils are the best lubricators for all purposes,

but it is true, that, in determining the value of mineral lubricants, those with the greatest viscosity are to be preferred. Concerning the general qualities of lubricating oils, and the methods employed in judging their value, we refer our readers to the chapter especially devoted to that subject. We propose, in this connection, simply to describe the method of determining the viscosity of an oil. Animal and vegetable oils are generally more viscous than mineral oils, and, while this property is closely related to the specific gravity, it is not directly proportional to it; vegetable oils are more viscous than animal oils, and the measure of viscosity of oils at ordinary temperatures is not to be assumed as a standard of the same oils at higher temperatures. "Tallow and castor oils are more viscous than sperm when cool, but they become very much more fluid when heated as in steam cylinders."[1] There are two methods of determining the viscosity of an oil:—

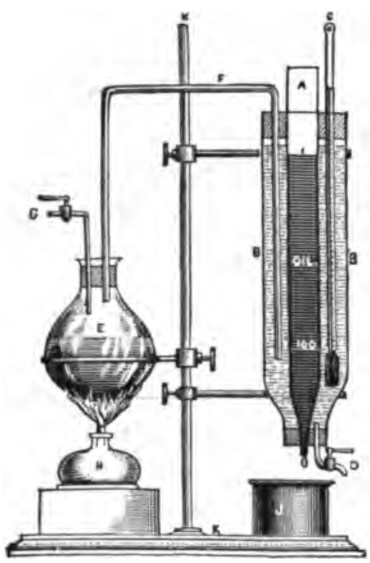
1st. By observing the length of time a measured sample of oil will require to pass through the small orifice of a pipette. The greater the viscidity of an oil, the longer the time it will require for the oil to pass through.

2d. By observing the length of time a sample of oil takes to pass from the top to the bottom of an inclined plane of glass or polished metal.

A very complete instrument (pipette), represented in Fig. 59, is thus described by Prof. Thurston.

[1] Thurston, On Friction and Lost Work.

Fig. 59.



Viscosity of Oils.

J. V. Wilson's Apparatus.

In the figure *A* is a glass-tube about 1 inch in diameter, graduated from 1 to 100, to contain about 100 cubic centimetres of oil. *B B* is a glass jacket about three inches in diameter, filled with water as shown. *C*, a thermometer indicating temperature of water in jacket. *D*, a small brass cock for withdrawing water from jacket. *E*, a glass flask for generating steam to heat water in jacket. *F*, a glass pipe connecting the steam flask *E* with jacket *B*, delivering at bottom of jacket. *G* is a small cock for permitting an escape of steam in order to regulate the amount sent into jacket. *H*, a spirit lamp on a stand. *J*, a glass beaker to contain oil, and *K*, cast-iron stand, with adjustable arms, for carrying the apparatus.

The following table gives the time required by each of several oils to flow through the orifice of the above-described apparatus, and the temperature observed in the same oils when used on a journal three inches in diameter, making 1500 revolutions per minute, the average being noted for an hour and a half. It is seen that, as a rule, the more viscous the oil, the more heat is developed by friction.

Viscosity of Oils.

Name of Material.	Specific gravity at 60° F.	Rate of Flow.			Temperature developed by test.
		60° F.	120° F.	180° F.	
Water	1000	...	...	...	...
Castor oil	960	...	132	41	158°
Rosin oil	990	...	...	...	155
Engine tallow	...	Solid	41	26	...
Tallow, or American oil	...	143	37	25	141
Neat's-foot oil	...	112	40	29	...
Rape oil	916	108	41	30	148
Lard oil	916	96	38	28	146
Olive oil	915	92	37	28	143
Sperm oil	880	47	30	25	133
Mineral oil No. 1	905	45	...	...	121
Mineral oil No. 2	875	30	...	...	117

It is evident that if the viscosity of an oil is to be determined by the time of its flow through an orifice, there are at least three conditions, which must be regulated either by legislation or common agreement: (1) The size of the orifice. (2) The temperature of the oil undergoing test; and (3) the quantity of the oil employed. The specific gravity of the oil should also be a matter to be taken into consideration. In the larger oil-distributing centres, there appears

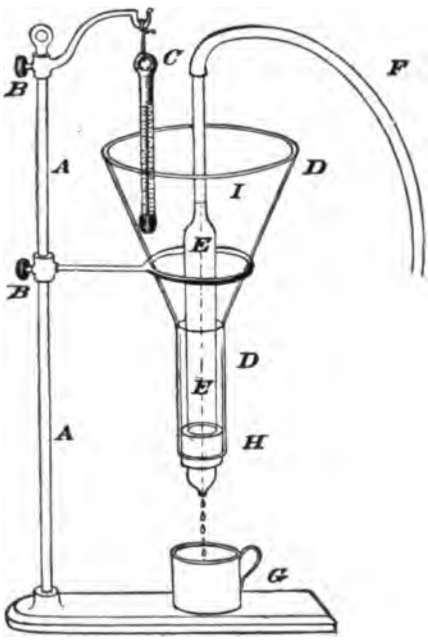
to be some understanding among dealers respecting these three important conditions. Mr. W. P. Mason, in the 'Chemical News,' 1884, proposes for general adoption a standard "viscosimeter," the dimensions of which are as follows:—

"A glass cylinder 22 inches (55.9 cm.) long, $1\frac{1}{4}$ inch (3.18 cm.) diameter, has a brass lower head $\frac{1}{8}$ inch (0.318 cm.) thick. An orifice is bored in the centre $\frac{1}{32}$ inch (0.794 cm.) in diameter, with bevelled edges, chamfered back $\frac{1}{2}$ inch (1.27 cm.), thus producing a sharp-edged orifice. A line marking the 18 inch (45.72 cm.) level is cut with several finer lines above and below, $\frac{1}{8}$ inch (0.318 cm.) apart, ranging from 16 to 21 inches (40.64 to 53.34 cm.) above the orifice. The standard temperature is usually 60° F. (15.5° C.). A total flow of 6.103 cubic inches (100 c. c.) is secured by adjusting the supply so that the head shall be as nearly as possible equal to 18 inches (45.72 cm.) of water, determining this head by calculation from the specific gravity of the oil. The rule for obtaining the viscosity is to note the time required to discharge the 100 c. c. (6.103 cubic inches) and divide this time by that required where water under a head of 18 inches (45.72 cm.) is used. This ratio is the measure of the viscosity."

Fig. 60 represents a form of "viscosimeter" in very common use, which in the hands of a careful manipulator will give uniform results. Its simplicity is certainly in its favor. *AA* represents an ordinary retort stand, with the adjustable arms, *BB*, for holding in position the glass funnel *DD*,

and thermometer, capable of holding about one gallon of water. *C* is a thermometer, *E E* is the viscosimeter proper, a glass tube swollen at the lower end, as shown in Fig. 60, and terminating in a minute orifice of standard size (0.037 in.

Fig. 60.



diameter). *F* is a flexible gum-elastic tube fitting with an air-tight joint to the upper end of this tube. The funnel is closed at its lower end by a tightly-fitting cork, in which an opening is made, through which opening the pipette passes and projects slightly below. *G* is a small vessel, either of glass or metal, of sufficient capacity to receive the contents of the pipette. In operating with this, it is necessary first to heat,

in a separate vessel, the water contained in the funnel, to the temperature of 60° F. The oil to be tested is brought in the same manner to the same temperature, and is put into the "viscosimeter" by gentle suction with the mouth upon the flexible tube until it exactly reaches the mark *I.* It is retained in position by a slight pressure with the thumb and finger until the operator with a "stop watch" indicating seconds is satisfied that all the conditions as to temperature and quantity of oil are satisfied, when the hand is withdrawn and the oil commences to flow or drop through the lower end of the instrument. The instant it ceases, the watch is stopped and the number of seconds consumed in its passage is the measure of the viscosity of the oil.

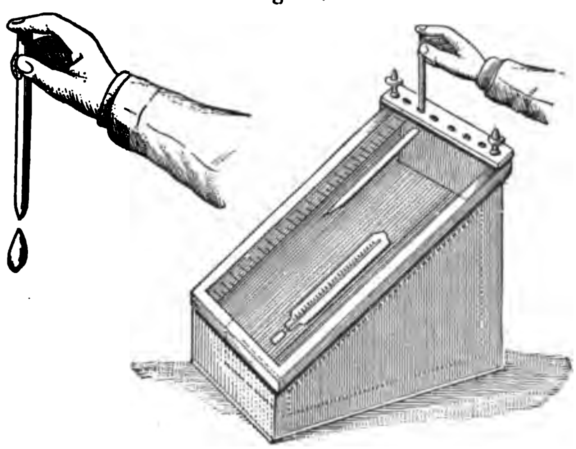
Testing the "Viscosity" by means of the Inclined Plane.

An apparatus for thus testing oils is thus described by Mr. W. H. Bailey, and is illustrated in Fig. 61. It consists of a piece of plate-glass set with considerable inclination and heated by means of a vessel of boiling water to about 200° F. and held at a uniform temperature as indicated by the thermometer attached. A drop of oil placed at the top will flow down. A scale on the side affords a convenient means of measuring the track of the oil. The length of time consumed in its descent is the measure of its viscosity. This form of apparatus is to be preferred to the pipette in testing animal or vegetable oils, as it also allows of observing any tendency to "gumming" which

is here permitted by its exposure to the oxidizing properties of the air.

While "viscosity," as tested in either of the above-mentioned apparatuses, is a most important feature in

Fig. 61.



Bailey's Apparatus.

judging of the quality of a lubricating oil, it must not be singly employed. Professor Thurston thus speaks of this test:—

"Large consumers of oil sometimes purchase on the basis of this kind of test only. It is regarded quite as satisfactory and reliable as any single physical or chemical test known, and as second only to the best testing-machine methods.

"The less the viscosity consistently with the use of the oil under the maximum pressures to be anticipated, the less is usually the friction. As a rule, the best lubricant is that having the least viscosity combined with the greatest

adhesiveness. The fluidity of an oil is thus to a large extent a measure of its value." We may, therefore, conclude that the oil which combines in itself the greatest fluidity with the most "staying" property, that is, of adhering to the journal, is the best oil.

Besides these, manufacturers who are close observers, have a variety of simpler tests, such as timing a ball falling through an oil column of known height; rubbing a portion of the oil between the thumb and forefinger; letting drops of the oil fall upon the surface of the same oil in bulk; exposing the oil for a few hours, or a day, upon the surface of a piece of glass. These tests (except the first) are not accurate, and oils are not bought or sold upon their indications.

IV.—The Composition of Oils and their Freedom from Admixture with other Oils or Foreign Substances.

It is absolutely essential that a dealer should have placed before him some reliable and easily-applied tests of the purity of the oils he is accustomed to handle. It is to be understood, however, that all mixtures of oil are not fraudulent combinations; such mixtures are continually made and sold for special purposes; notwithstanding this, when a mixture of 5 per cent. of sperm oil and 95 per cent. of "neutral" mineral oil can be sold for pure sperm, it is very desirable to know just what such a mixture is made of. The tests which are applicable here, are partly chemical and partly mechanical. We will consider first those

which belong to the domain of chemistry, and propose to confine our remarks exclusively to the detection of admixtures with petroleum oils. The consideration of combinations of animal or vegetable oils, containing no petroleum, does not come within the scope of this volume. The outlines of the process for the detection of a mixture of petroleum and other oils will be found in the examination of the density; a lower flashing or burning point, would indicate the presence of a mineral oil. Fluorescence would positively betray petroleum. Finally, the incomplete saponification of the sample would be conclusive. The following method of conducting this strictly chemical test is taken from a paper by Mr. Alfred H. Allen, published in the 'Oil and Drug Reporter,' October 18, 1881.

"The best and most accurate method of detecting hydrocarbon oils in, and quantitatively separating them from, fat oils, is to saponify the samples and then agitate the aqueous solution of the soap with ether; or by separating the ethereal layer and evaporating it at, or below, a steam heat, the hydro-carbon oil is recovered in a state of purity. Either caustic potash or soda may be employed for the saponification, but the former alkali is preferable, owing to its greater solubility in alcohol and the more soluble character of the soaps formed. A convenient proportion to work with consists of 5 grms. of the sample of the oil and 25 c.c. of a solution of caustic potash in methylated spirit, containing about 80 grms. of KHO per liter. Complete saponification may usually be effected by boiling down the mixture in a porcelain dish, with frequent stirring until it

froths strongly. After evaporating off the alcohol, the soap is dissolved in water and agitated with ether. The ethereal solution is separated, washed in a little water and carefully evaporated. The agitation with ether must be repeated several times to effect a complete extraction of the hydro-carbon oil from the soap solution."

The foregoing process has been proved to be accurate on numerous mixtures of fat oils with hydro-carbon oils. Sperm oils and spermaceti, however, are remarkable exceptions, as neither of these is wholly saponifiable. The following table, furnished by Mr. Allen, gives the result of his experiments with this test.

Composition of substances taken.

Fat oil.	Results.	Hydro-carbon oil.	Results.	Unsaponifiable matter found.
	per cent.		per cent.	per cent.
Olive	40	Shale oil . .	60	58.03
Olive	80	Shale oil . .	20	19.37
Olive	40	Rosin oil . .	60	59.42
Olive	80	Rosin oil . .	20	19.61
Rape	86	Shale oil . .	16	15.95
Cotton-seed .	60	Rosin oil . .	40	39.74
Linseed . .	60	Rosin oil . .	40	39.32
Castor . . .	60	Rosin oil . .	40	38.88
Cod-liver . .	70	Rosin oil . .	30	30.80
Lard	60	Paraffine wax .	40	39.54
Lard	20	Paraffine wax .	80	80.09
Olive	100	. . . . .	. . .	1.14
Rape	100	. . . . .	. . .	1.00
Castor . . .	100	. . . . .	. . .	0.71
Cod-liver . .	100	. . . . .	. . .	1.82
Palm	100	. . . . .	. . .	0.54
Butter fat . .	100	. . . . .	. . .	0.46
Sperm . . .	100	. . . . .	. . .	41.49
Spermaceti .	100	. . . . .	. . .	49.68
Japan wax . .	100	. . . . .	. . .	1.14
Lard	100	. . . . .	. . .	0.23
Cacoa butter .	100	. . . . .	. . .	0.22

The mechanical tests referred to include filtration for the separation of foreign matter, and the critical tests for fluorescence.

Petroleum, either crude or refined, when perfectly free from admixture of any kind, is highly refractive of light, and presents a brilliant lustre.

In the crude state, it is usually too opaque to be tested by transmitted light except in very small quantities or in thin layers, as when spread upon a polished surface of glass; a very small percentage of water dims its appearance. This is readily shown by heating a portion of the oil, when frothing takes place upon the surface and continues until the last trace of moisture is expelled.

Fluorescence, a remarkable peculiarity of petroleum oils, for some reason which we cannot appreciate, is considered an objectionable feature. I know of no reason why it should be so considered, or why so many methods are contrived to destroy it, excepting that petroleum is so often employed as an adulterant to more expensive oils, on which account it is desirable to remove so persistent a quality. In most cases it is evident upon first sight. The least trace of fluorescence is rendered apparent by pouring a small portion of the oil upon a polished plate of black glass, or upon a piece of glass thickly coated upon one side with black paint. The film of oil spreads itself upon the surface of the glass, and as this is turned at different angles to reflect the light properly, the fluorescence, if any, is plainly shown.

V.—Its Natural Composition by Actual Assay.

This test provides for the detection, not of foreign admixtures, but for fraudulent combinations of petroleums of different gravities and inferior qualities, and is applicable to both crude and refined oils. It is quite possible to so combine portions of residuum, paraffine oil, and benzene, that it would be difficult to detect a fraudulent mixture without this process. It might possess all the usual appearances of natural crude oil, as to color, odor, and gravity, and yet be valueless for the purpose of refining. The New York Oil Exchange have established the following rule regarding the delivery of crude oil:—

Rule IV. "Crude petroleum shall be understood to be *pure natural oil*, neither steamed, nor treated, free from water, sediment, or any other adulteration of the gravity of 43° to 48° Baumé."

The rule has been subsequently modified as to gravity, as very much of the natural crude oil now produced is of a lower gravity than 43°. The rest of the rule remains in force.

The test employed is one based upon actual distillation in an apparatus in all respects similar to the large stills employed in refining oils. The apparatus employed by Lockwood Bros. & Holly, petroleum importers, of Philadelphia and New York, is a small copper still modelled precisely and according to scale, after a 2500-barrel still of the cheese-box pattern. The condensing apparatus is built upon the same model. This experimental still holds

1000 fluid ounces; the heat is supplied by a gas furnace. The distillate is divided into nine portions of 100 fluid ounces each, and the gravity of each portion taken; the residuum constitutes the tenth division of the oil undergoing test. A record of the gravity of these different portions is preserved by the inspectors, and a copy of the same in the form of a certificate is furnished to the buyer. The following may serve as a specimen copy of a record of the assay of two samples of crude oil:—

Oil from Parker District. Gravity 46 Baumé.		Oil from Bradford District. Gravity 43 Baumé.	
1st product	72	1st product	71
2d "	62	2d "	60
3d "	57	3d "	54
4th "	53	4th "	49
5th "	49	5th "	45
6th "	46	6th "	41
7th "	42	7th "	40
8th "	41	8th "	41
9th "	42	9th "	42

Although the analyses of these two samples of oil show a marked difference in the gravities of the distillates, still, the regular gradation of these as they issue from the condenser plainly indicates a natural product, and that the "middle cut" of the oil has not been removed and its place fraudulently supplied.

This test is demanded on all shipments of crude oil to foreign ports. Purchases made from the pipe-line companies are not subjected to this examination. These companies have their own agents at the wells to examine all deliveries of oil into their tanks.

VI.—The Degree of Cold to which Oil may be Exposed without the Deposition of Crystalline Paraffine.

This test is chiefly applied to lubricating oils, although it is equally applicable to refined oils.

It is quite unnecessary to repeat here what has already been said respecting the tendency of the heavier petroleum oils to deposit paraffine at low temperatures. The value of lubricating oils is just in an inverse ratio to this tendency, and they are rated accordingly. The test consists simply in exposing the sample undergoing test, to chilling, in a suitably contrived ice-chest fitted with thermometer. Fig. 62 represents a very complete and efficient contrivance for the purpose, and its accuracy may be relied on. The following "cold-test rule" is the one adopted by Messrs. Lockwood Brothers & Holly before referred to.

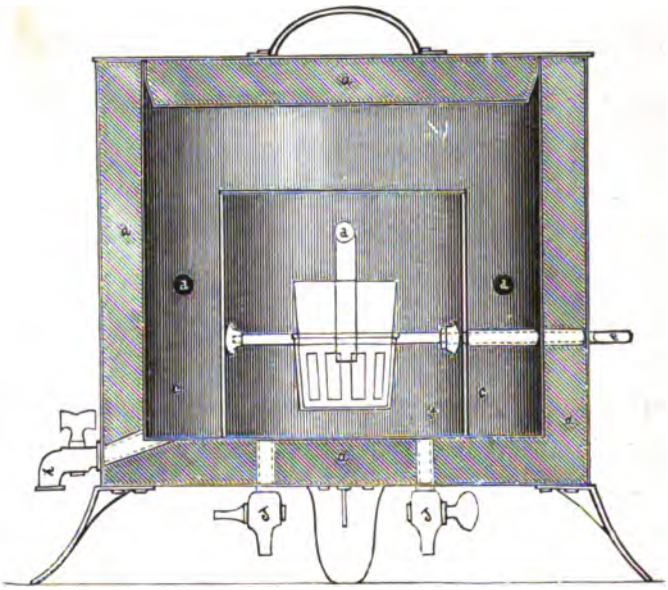
"*Cold-Test Rule.*"

There shall be placed in a glass vessel four inches in depth and three inches in diameter, the oil to be tested; the vessel to be in an ice-chest. A thermometer is to be placed in the centre of the oil-glass and another thermometer outside of said vessel, but in the ice-chest. When the two instruments reach the required point and indicate the same temperature, if the oil is still limpid, it shall be taken as a proper cold-test.

Oil Samples.

Samples of oils are usually exhibited in small cylindrical bottles five and a half inches long, one and a half in

Fig. 62.



Sectional View of Tagliabue's Standard Oil-Freezer.

The freezer is a semi-cylindrical metallic stand, neatly japanned, divided into three compartments :—

The first *f*, is the Oil-Cooling Chamber, in which is the receiver, adjusted to a rocking shaft *g*, to facilitate the introduction of the regulation Oil Cup therein, and to show by its motion whether the oil is congealing or not.

The second, *c*, is the Ice Chamber, which is filled with ice and rock salt for the cooling process; a faucet, *h*, is connected with it, to allow the melted ice to flow out.

The third, *a*, is a non-conducting Jacket, lined with PATENT MINERAL-WOOL FILLING, to maintain an even temperature in the Cooling Chamber, and to prevent a too rapid melting of the ice.

Three Thermometers, *d*, are inserted in the Freezer—one on each side of the Cooling Chamber, to denote its temperature; and a third one in the centre so adjusted that its bulb, penetrating the middle of the oil, enables the expert to see through a glass door (without opening the same, and thereby preventing atmospheric changes) at what temperature the oil commences to congeal.

Two STOP-COCKS, *j*, are attached to the bottom, communicating with the Cooling Chamber, to force therein (by either opening or blowing through them with a rubber tube) atmospheric or warm air, whenever it is desired to raise its temperature.

diameter, of pure white glass. This is the regulation standard. A small label is attached to the sample, bearing the maker's, or inspector's, name, with the following information:—

Name of oil ....
Number of barrels ....
Color ....
Fire-test ....
Cold-test ....
Viscosity ....
Gravity ....

With the character of the oil thus disclosed in the description, the buyer need never go astray in the purchase of his supplies.

CHAPTER XI.

PETROLEUM IN MEDICINE AND PHARMACY.

SOME slight allusion has already been made to the employment of petroleum in the treatment of certain diseases of men and other animals, and yet, notwithstanding the fact that the records of such use date from the earliest times, it has never, until within a few years, obtained an established place in the pharmacopœia of any country. It has long enjoyed a reputation as an outward remedy, in a variety of cutaneous diseases, and the men employed about the oil wells, both in this and foreign countries, resort to it as a sovereign cure for rheumatism, sprains, and bruises. It is an ingredient of a number of patent nostrums, which have sustained a long and successful run, and are still in use. If there be any virtue in the well-known "specifics" "Harlem Oil," "Turlington's Balsam," "British Oil," it is due to their chief remedial constituent—petroleum—and that in its crude state. Gaseous petroleum has a marked effect upon the system, resembling very much that of nitrous oxide or "laughing gas," first intoxicating, then stupefying, and resulting, if continued, in fatal consequences. Its peculiar qualities in this respect were noticed in the issue of the 'Scientific American,' October 17, 1885:—

"Recently at the American Rubber Company's Works,

Cambridge, Mass., a number of girls in the coat-room were suddenly overcome by the fumes of naphtha used in the cement on the seams of the coats. One of the girls suddenly began to laugh loudly and acted strangely and then fainted. Several others also dropped upon the floor, and before physicians could be summoned more than thirty employés were unconscious or in hysterics. The alarm spread to the other employés, but they were soon quieted by the foreman in charge, and the girls most seriously affected were sent to their homes in carriages. No serious results are anticipated in any of the cases."

The most volatile liquid product of the distillation of petroleum, rhigolene, specific gravity .625, which is the lightest known liquid, has been frequently employed as an anæsthetic in surgery, both by way of inhalation and in the spray or freezing process. This much at least has been determined, that, whatever remedial virtues may exist in the crude petroleum, they belong exclusively to its most volatile constituents, as the heavier residual products and pure paraffine are entirely destitute of any effects upon the human system. The popular "chewing gum" is composed largely of paraffine, and is destitute of deleterious effects. The crude oil is powerfully destructive of insect life, and, in the region of the wells, is largely used to protect men and animals from the attacks of mosquitos and as a protection from a poisonous gad-fly. Mechanically incorporated with soap, it is a most effectual remedy for lice, "mange" or "scab" on dogs and sheep. It has also been successfully employed for ridding plants of parasites.

Moths in garments and carpets are completely removed by a bath in naphtha.

Up to the present time, however, notwithstanding the marvellous cures which have been attributed to its use, it cannot be said to have obtained the confidence of intelligent, scientific medical men. As long as such "cures" as the following are attributed to it we can well understand this lack of faith: "A sample of Barbadoes petroleum was sent to the editor of the 'American Journal of Science' with the following statement: The tar is found very useful in preventing lockjaw, when the first symptoms are attended to, by rubbing the spinal bone from end to end and the muscles of the thigh and arms." Our space will neither allow, nor would it avail anything, to mention other therapeutical uses to which it has been applied.

Petroleum in Pharmacy.

In this connection we have quite another record to make concerning this curious substance. Perhaps no more important contribution has been made to our Pharmacopœia for a number of years, than the dense product known, variously, as vaseline, cosmoline, petroline, etc. The manufacturers of this material, which is found in the market under these various names, claim protection for their products under the patent laws. It is shrewdly suspected that the true secret of the process of their manufacture does not find a place in any of their specifications. Stripped of all verbiage and circumlocution, the article known as cosmoline, etc., is

neither more nor less than amorphous paraffine with a low melting-point. It is a pale yellow, translucent, slightly fluorescent, semi-solid substance. It was made the subject of special analysis and examination by Mr. J. Moss, whose paper was read at the meeting of the Pharmaceutical Society, February 2, 1876. "It melts at about 100° F., having a specific gravity of 0.850. It is insoluble in water, slightly soluble in alcohol, freely so in ether, and miscible in all proportions with fixed and volatile oils. It is not acted upon by hydrochloric acid or solution of potash, and has all the other characteristics of a mixture of paraffines. An ultimate organic analysis made by him gave 97.54 per cent. of hydro-carbons. Under the microscope, vaseline, in common with most other fats, is found to contain numerous small acicular crystals, doubtless consisting of a paraffine of a higher melting point than the mass; but these do not in any way interfere with its usefulness because of their extreme minuteness and easy fusibility. Vaseline may be kept indefinitely without becoming rancid, and this, together with its indifference to chemicals and its readiness to take up any perfume, is sufficient to recommend it for pharmaceutical and toilet purposes in place of the fats generally used."

In the preparation of ointments, cerates, etc., it is in many respects very far superior to the animal or vegetable fats hitherto employed. Having no chemical affinity or action on any of the medical ingredients used, ointments compounded with vaseline as a base remain unchanged for years. Some of the ointments of the United States Pharmacopœia, as, for instance, citrine ointment (ung. hydrarg.

nitrate), which have been found exceedingly difficult to retain in good condition even for a few weeks, may now be prepared with vaseline to keep indefinitely. Simple cerate, "cold cream," so highly esteemed for excoriated surfaces, but frequently found rancid, may now be had in perfect condition. The author may divulge a "French" culinary secret in stating (but with how much correctness he is not positive) that this curious product of petroleum has found a useful place as a substitute for olive oil in frying meats and oysters. Being absolutely free from taste or smell, and quite harmless, it is said to be superior to any of the fats hitherto employed for such purposes.

Vaseline is prepared from the "residuum" of the distillation of petroleum conducted on the vacuum process. This residuum is placed in settling tanks, heated by steam, in order to keep their contents in a liquid state. After the complete separation of the fine coke, it is withdrawn from these tanks and passed through the bone-black cylinders, during which process, the color is nearly all removed, as well as the empyreumatic odor. It is supplied to the trade in tin cans containing from one to ten pounds, and to the retail trade in small, wide-mouth bottles, frequently perfumed. As thus supplied, it is a most useful and delightful addition to the toilette.

The manufacturers of petroleum ointment in Germany, who use the term vaseline almost exclusively to designate the product, employ as raw material "mountain tar," that is, crude ozocerite, from Alsace and Galicia, and residues of American petroleum, which are of semi-liquid or

unctuous condition and yield a correspondingly softer or denser vaseline.

The purification and decoloration of the raw material are accomplished, either by treating with sulphuric acid and bichromate of potassium and subsequent digestion with animal charcoal, or, by treating it with the latter substance alone. In the following, we describe two processes, furnished by two German factories. The first one accompanies a petition for the granting of the privilege of establishing the works; the second was communicated by the manufacturer.

First Process.

1. The oil is heated by steam to about 30° C. (86° F.), mixed at this temperature with 10 per cent. of its weight of sulphuric acid of 60° B., stirred for half an hour and then allowed to rest, so that the carbonized portions may separate.

2. When clear, the oil is washed with an aqueous solution of bichromate of potassium, whereby any remaining excess of sulphuric acid is, at the same time, removed.

3. The residue from the acid treatment is mixed with lime, neutralized and disposed of to manure factories.

4. The clear oil from the second step of the process, after being washed, is heated by steam to 80° C. (176° F.), mixed with 10 per cent. of its weight of granular animal charcoal, and then allowed to rest, to permit the animal charcoal to settle.

5. After the latter is separated, the liquid portion is filtered through filters heated by steam.

6. The residue is subjected to hydraulic pressure, the expressed oil filtered, and the solid portion again used in the next operation, a sufficient quantity of fresh animal charcoal being added to make up for any loss or waste.

Second Process.

The raw materials, petroleum-residuum or natural ozocerite, are rendered fluid, and the liquid, after the separation of all extraneous matters, is passed through a series of charcoal filters such as are used in sugar refineries.

After passing through twelve to fifteen of these cylindrical filters, the original brownish-black color of the liquid has become wine-yellow. To render it colorless and limpid as water, double the number of filters are required. The liquid acquires a lower specific gravity the less colored it becomes, but when it has become colorless, the specific gravity remains stationary no matter how long the filtration may be continued. After it has thus been freed from all bituminous matter, it is transferred to the "duplicator," where it is brought in direct contact with superheated steam and the temperature is allowed to rise to 250° C. (482° F.). Samples taken occasionally from the boiler should show no changes in the product after this temperature has been kept up for a few hours. The finished vaseline, amounting to about 25 or 30 per cent. of the raw material, is finally filtered and filled into cans for shipment.

A great drawback in this method is the rapid exhaustion of the animal charcoal, which is only able to decolozire a small percentage of its own weight of crude vaseline. It is, therefore, necessary to provide extensive facilities for extracting the portion of vaseline retained by the charcoal and to regenerate the latter, which may be done by superheated steam at a temperature of 400° to 500° C. (752° to 932° F.). It is for this reason that most factories use sulphuric acid for purifying, by means of which the material may be brought to the color of beer, so that only about one-third as much charcoal is required for final decoloration. It is, however, almost impossible to get rid of the last traces of the chemicals employed, and for this reason the quality of the vaseline obtained by the other process is much superior. It is pure white, like the best tallow, and entirely tasteless. It is also odorless, not only when rubbed upon the hand, but also when melted in water; the latter property distinguishing it from all other varieties, which, on melting in water, develop a faint odor of petroleum. When melted, it yields a clear colorless liquid, which, on cooling, returns to its former homogeneous condition. Cold 98 per cent. alcohol dissolves, on shaking, 2.2 per cent. of vaseline. The residue left on evaporating the alcohol is liquid at ordinary temperatures. Hot alcohol dissolves it completely to a clear solution. On cooling the vaseline separates in flakes. It behaves in the same manner towards benzol and ether, but is not completely soluble in the latter even on warming. It does not impart an acid reaction to water, and is not affected by solution of

potassa. Boiling sulphuric acid, of 1.600 specific gravity, and boiling nitric acid, of 1.185 specific gravity, have no effect on it. Fuming nitric acid colors it yellowish-red, and sulphuric acid of 1.820, grayish-black. The acid itself acquires a yellowish-brown color. The specific gravity of the vaseline is 0.848.

5 grams (2.82 drams), heated in a closed tube for several hours with oxygen, absorb from 4 to 5 cubic centimetres. Its odor is thereby rendered only very faintly acid, and its ethereal solution has only a very slight acid reaction on blue litmus-paper.

Benzene in Pharmacy.

The next most important contribution to pharmacy is the employment of benzene in extracting from plants and vegetable substances, such as seeds, etc., the essential and fixed oils, and many of the active principles. It is claimed that the essential oils so prepared have a flavor superior to those prepared by the ordinary process of distillation. M. L. Wolf, of Philadelphia, who has made some valuable contributions to our knowledge on this subject, described a process in the 'American Journal of Pharmacy' for the manufacture of *apiol*, and claimed his product to be a preparation equal in every respect to the high-priced French article.

CHAPTER XII.

PETROLEUM AS AN ILLUMINATOR.

THE observation that the man who makes two blades of grass grow where only one grew before, is a benefactor to his race, finds an analogy in the assertion that he who practically adds to the span of man's life by increasing the number of hours wherein he can labor or enjoy himself, is also a benefactor.

The nineteenth century has been marked in its course by a greater number of inventions and improvements, promotive of human civilization and happiness, than any like period preceding it, and, perhaps, no feature of its record is more significant or beneficent than the improved methods of lighting our dwellings, brought into use largely through the instrumentality of the great light-bearer, petroleum. Its welcome, cheerful, steady flame gladdens the cabin of the Western emigrant on his trail through the trackless forest, and lights up the hut of the Colorado miner. It cheers equally the home of the thrifty farmer, and the rude quarters of the humblest laborer. Its bright rays lend their kindly aid to the thousand homely cares, which give zest and happiness to the family circle. Thus the sum of human knowledge is increased and the aggregate of wealth added to by the useful occupancy of hours

snatched from darkness and sleep, and thus practically man's life has been extended, and his opportunities for usefulness increased. The circumstances, which have led up to the present general use of the hydro-carbon light, are varied. The torch or flambeau of the Russian peasant of the Caucasus, or the rude smoky lamp of the Rangoon laborer, afforded a small margin to the inventor to hope for improvement. The excess of carbon in the "earth oil" used by these, would not permit the same appliances in use for the refined and pure vegetable oils then employed; nevertheless, the great abundance in certain localities of this "earth oil" overcame by degrees the repugnance to its use, occasioned by its disagreeable odor, both in its natural state and when it was being burned. No efforts had yet been made either to purify it, or to construct suitable lamps to use it. Its chemical composition was either wholly undetermined, or remained locked up in the memoranda of the chemist. It was not even suspected, that the large proportion of carbon it contained, required a special burner to secure thereby a large supply of oxygen, by which its best illuminating effects could be developed. M. Felix Foucon, in an article in the 'Revue des Deux Mondes,' very interestingly alludes to the part which the several nations have contributed in bringing so useful a discovery to perfection.

"In the domain of the useful arts, each age reveals characteristic tendencies. In the last century mankind had need to clothe themselves cheaply. It was this, that made the fortune of Arkwright and the machine-spinners, the

sudden prosperity of Manchester, and the Continental cities which imported the new method of labor. The nineteenth century has wished for light, both in the birch-bark wigwam of the Indian, and in the mud cabin of the poor Ruthenian of Galicia. The introduction of the most modest lamp gives activity to family life in prolonging the evening's labors. France has largely contributed to this result. The invention of Argand, which was the first progressive step in advance of the smoky candle-stick of ancient times, arose painfully at the eve of the French revolution. The Carcel lamp and gas are of yesterday; a crowd of obscure inventors have with unremitting labor perfected the mechanism of lamps in order to escape the costly necessity of burning vegetable oils. These experiments, many of which were undertaken under the monarchy, prepared the way for the success of petroleum; unfortunately they came at a moment when it was premature to dream that illumination by mineral oil would become universal. The material was at first wanting; chemistry had not furnished a method of extracting those precious substances from the schists, with which they were found associated at many points; and science had not yet shown the part that liquid petroleum, of which a great many springs were then known, was destined to play.

"It is to the Americans that the merit belongs of having elevated petroleum to its present rank among the industries. The native talent that led them to regard the useful aspect of everything, above all their feverish but patient activity, seconded so well by a happy temperament, has served them

marvellously in this instance. The French chemist Selligue, gave them the first experiments in the basin of Autun about the year 1832, by distilling on an industrial scale the schists that abound in that part of France. Mr. James Young, of Glasgow, perfected the process and established, in 1847, in Derbyshire, a vast manufactory for treating the English minerals, incomparably richer than those of France, and known under the names of Boghead and Cannel coal. In a few years this establishment took on an extraordinary development, and yielded its projectors several hundred thousand francs of revenue. The prospect of such profits so soon realized placed this manufacture in a reputable position. It extended to the United States in 1854, when it was employed upon the Scotch Boghead and several indigenous schists. In 1860, there were in North America, 64 manufacturers of schist oils. The discovery of abundant reservoirs of petroleum suddenly arrested this growing industry, ruined a number of manufacturers, and led others to change their factories into refineries of petroleum, that substance being much richer in illuminating material than Boghead or Cannel coal."

Without touching upon matters which properly belong to the history of the petroleum industry of the United States, it will serve to illustrate the rapidity of the growth of the employment of petroleum to place just here in juxtaposition the amount of oil produced in 1860 and the yield in 1884.

Amount produced in	1860 . . .	500,000 barrels.
" "	1884 . . .	23,500,000 "

The production for 1884, as given, does not represent the total yield of petroleum for that year, as these figures do not include the heavy lubricating oils from West Virginia and other places. The yield of these, which command a higher price per gallon, is small in proportion to that of the lighter varieties employed for illumination.

The methods of using petroleum for illumination may all be included in the following :—

I. As a torch oil.

II. In lamps provided with chimneys.

III. In lamps without chimneys, but with special clock-work arrangement, for furnishing increased aëration to the wick.

IV. In the manufacture of carburetted-air by the passage of air through gasolene.

V. In the manufacture of gas, either from ordinary crude petroleum, or, as it is more generally made, from the heavier oils, or from the residuary products of the still.

VI. In vapor burners, in which benzene of light gravity is used and burned at the instant it is vaporized.

I.—As a Torch Oil.

Very little need be said respecting this mode of burning petroleum ; there is nothing in it to be commended. The lamps used are not better than those to be found in the ruins of Pompeii, and the oil far inferior for the purpose to the pure olive oil employed by the inhabitants of that

buried city. A torch oil used by miners is variously compounded, having sperm for its basis. Refined petroleum is only added as an adulterant and in proportions to suit the views of purchasers.

II.—In Lamps provided with Chimneys.

By far the largest proportion of petroleum used for illuminating purposes is burned in lamps provided with glass chimneys, for the purpose of increasing the draught, thereby supplying the additional quantity of oxygen needed in the combustion of these hydro-carbon oils, in which the carbon element so largely predominates. In the construction of these lamps, in order to secure the greatest brilliancy of light, it is absolutely indispensable to have some knowledge of the physical and chemical qualities of the material consumed in them. For example, oils of light gravity may be used with good effect in lamps provided with a deep receptacle; an oil of heavier gravity, or an oil containing light and heavy oils mixed, would soon indicate by a drooping flame, that a receptacle so formed was not the best adapted to it. Some allusion has already been made, in the chapter on Oil Tests, to the expedients employed for judging of the qualities of illuminating oil. It has, however, been left until the present to speak of certain peculiarities of the different kinds of illuminating oils found in commerce, which come more particularly under the eye of the consumer, or, in other words, to treat of those practical tests open to common observation in the use of the oil.

There are in use many grades of oil, but, for brevity sake, these may be classed under three heads, viz., "prime," "standard," and "water-white." These are commercial grades. Different manufacturers attach different names to the same quality or grade of oil, but with these (fancy) brands we have no concern. In the early days of petroleum refining, before the process of "cracking" was introduced, "prime," as its name would indicate, was considered the best oil manufactured. It was of a very pale straw-color, and was produced by a regular distillation without any checking of the operation, until the color of the distillate became too dark to proceed any further. The chemical treatment was substantially the same as that employed at present. If carefully distilled under this process, an oil of excellent quality was the result. It produced a clear, steady light, which would not droop as the quantity of oil lessened in the lamp. Under the "cracking process" it became possible to return to the body of undistilled oil, the condensed vapors of the dark, heavy oils, by which they were decomposed, and an additional quantity of light-colored oil was obtained; thus was secured a much larger yield of light-colored oil, resulting in establishing in the market a higher grade of oil, known as the "standard," which is perhaps two shades lighter in color than the "prime."

It becomes a question of importance, certainly, to consumers, to decide whether the "cracking process," as ordinarily conducted, is not an injurious one. I am not prepared to say that it is, but there are some high author-

ities who maintain that it is, and bring to their support some strong arguments in the shape of practical tests. The photometric tests to which "cracked" and "uncracked" oils have been subjected, do appear to indicate that oils of the former class have suffered in light-giving power. The results of these experiments are before me, but without more definite information respecting the exact method practised in the distillation and treatment of the several samples of oil experimented on, I do not consider them conclusive.

From all that has been said respecting the means of judging of the quality of oils, it is evident there is no one test to be relied upon, but when the several tests which have been described, have been applied, we may arrive at a correct judgment respecting it. A very simple photometric test, within the easy reach of every one, is here given. This test, when fairly made with lamps of the same size and construction, reveals more than any one single test that can be mentioned. Not only is the quality of the oil at the commencement of the test shown, but, as the two lamps burn quietly together, the real composition of the two samples is clearly manifested. They may, at the beginning, give out the same amount of light, but the rate of consumption may vary considerably, thus indicating a difference in density; or, the light of one may perceptibly droop as the oil sinks in the lamp, indicating that there is an undue preponderance of heavy oil. The test consists in taking two ordinary petroleum lamps, filled respectively with the oils to be compared, and placed side by side in

such a manner that a shadow shall be projected on a white surface, from a rod or other object, placed at an equal distance from each lamp. The darker shadow is cast by the brighter light. By a close observation of these shadows throughout the whole operation, we may obtain a tolerably accurate estimate, not only of the quality of light afforded by each, but of the relative money value of each.

It should be noticed in this place, however, that the abundance and cheapness of the lighter products of the refinery, have exposed the public to serious danger from the adulteration of kerosene with the lighter and cheaper products. Kerosene thus adulterated is extremely dangerous when burned in lamps; it may explode from carelessness or ignorance on the part of the user, in attempting to replenish the oil while the lamp is burning; and, should the lamp fall and break, the burning wick may ignite the oil, and thus place property and human life in imminent peril. The large number of accidents recorded yearly, from the upsetting or the explosion of oil lamps, affords evidence that the danger from this source is not exaggerated. The laws regulating the inspection of petroleum, and defining the grade of oil that shall be approved for domestic use are explicit enough, and if properly enforced would afford ample protection. In the great majority of localities, however, *the adulteration of kerosene with the cheaper benzene is carried on with impunity.* This fact cannot be too strongly impressed on the purchaser, and, in order to guard against this dangerous fraud he should not omit to make, in every case where there may be any

doubt, the following simple experiment, which will indicate with sufficient accuracy whether a specimen of oil is, or is not, fit to burn, in a lamp of the usual construction: viz., pour a tablespoonful into a saucer or other convenient receptacle, and touch it with a burning match. If it takes fire, reject it as adulterated with benzene; if it will not take fire, but extinguishes the match, it may be accepted as safe without hesitation. The application of this simple test, which can be performed by the most inexpert person, before purchasing oil for the household lamp, would do away with nearly all the distressing accidents that are of such common occurrence.

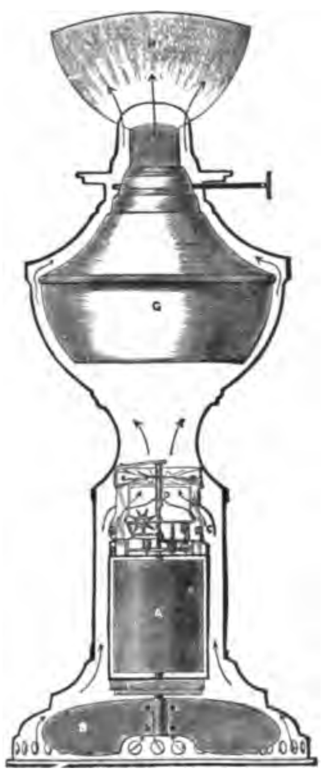
Closely connected with the satisfactory use of petroleum as an illuminant are the composition and quality of the wick. Far too little attention has been paid to this seemingly unimportant part of a lamp. It has been generally supposed that any fibrous material capable of exerting capillary attraction would answer the purpose, but it has been found by accurate photometric tests that cotton is the best material, and that any fraudulent mixture of a different fibre may be instantly detected by a diminution of light.

III.—In Lamps without Chimneys but with Special Clockwork Arrangement for Furnishing Increased Aëration of the Wick.

Lamps so constructed have a revolving fan to force a current of air through and around the wick. The principle involved in their use will be best understood by the illus-

tration (Fig. 63) of the Hitchcock table-lamp. This form of lamp answers a good purpose, in avoiding the annoyance of broken chimneys. It furnishes a bright, steady light, and affords a practical substitute for the ordinary lamp.

Fig. 63.



The diagram shows how sufficient oxygen is delivered at the point of combustion. *A* is a clockwork which, when fully wound up by the key *B*, runs ten hours. This, by a series of wheels, drives the fan *E E*, which delivers a constant current of air in the direction marked by the arrows. This

air circulates around the oil receiver *G*, keeping it cool, and in its upward course impinges upon the flame *H* as it passes through the burner. The flame is thereby sufficiently oxygenated to give the fullest volume of light—the force of the mechanism being adjusted for that purpose, and giving to tinted fabrics the proper appearance by night.

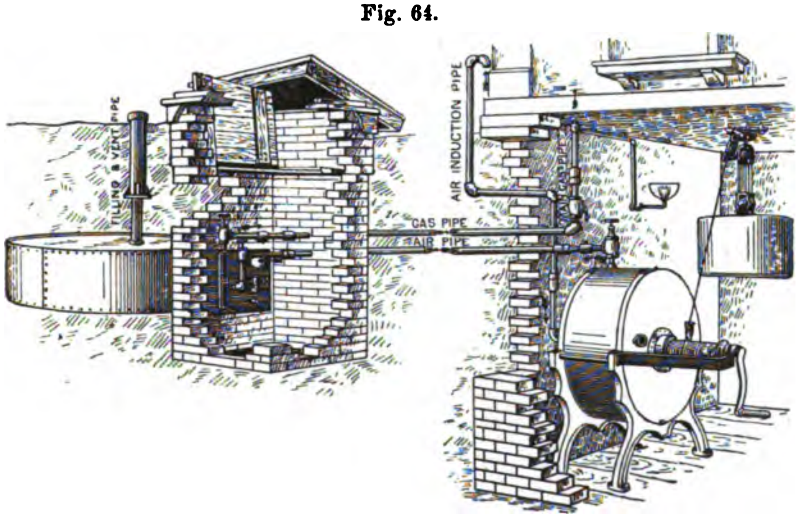
IV.—In the Manufacture of Carburetted-Air by the Passage of Air through Gasolene.

Next to the use of oil in the ordinary lamp, this process furnishes the most convenient and successful plan of using the distilled products of petroleum. The principle of the operation consists in the power of ordinary atmospheric air to absorb in its passage through gasolene of light gravity, sufficient of this material to render it equal, or even superior, to ordinary coal gas in its luminiferous properties. A large number of patents have been granted for different machines or contrivances to effect this carburetting process, or, in other words, the saturating of the air with gasolene vapor. The main features of these are an air-pump of a rotatory pattern, to receive the air and force it, and second, the carburetter or gas generator. The air-pump may be driven by a suspended weight, by a coiled spring of steel, or by water power.

The cost of the manufacture of gas from gasolene is about 80 cents per 1000 feet, with the material at 18 cents per gallon. A typical machine of this class is represented in Fig. 64. In this, the air-pump and its appur-

tenances are placed in the cellar of the house, and the carburetter, containing the supply of gasolene, is placed underground, at a distance of fifty feet or more from the house. Suitable pipes, indicated in the cut, convey the air from the air-pump to the carburetter and bring the carburetted-air from this to the house, where it is burned

Fig. 64.



Gas Generator. Air Pump.

Machine Set up Ready for Use.

in fixtures of the same description as those used for ordinary illuminating gas. Where these machines are set up in the manner exhibited in this illustration, and provided with automatic means for preventing the reversal of the air current, and the flooding of the cellar with gasolene and its vapors, they are approved by the insurance companies. They afford a capital substitute for illuminating gas in all situations where the latter is not available, and have been very largely introduced.

V.—In the Manufacture of Gas, either from ordinary Crude Petroleum, or, as it is generally made, from the Heavier Oils, or from the Residuary Products of the Still.

Owing to the abundant supply of petroleum in this country, to the simplicity of apparatus required, and to the superior product obtained, much attention has been paid to this subject. A large number of patents, covering almost every conceivable form of retort and burner, have been secured. The gas obtained from petroleum is far richer in light-bearing properties than the ordinary coal gas, and, before it is burned, requires a large dilution with atmospheric air. The principle concerned in its manufacture consists in its decomposition into gas and vapor, by its passage through red-hot iron pipes, or some other vessel equivalent to a retort.

This gas requires in its manufacture no expensive washing or purifying arrangement. Petroleum gas has also been employed extensively as an *enricher* of ordinary gas, either by admixture of oil with the coal in the process of manufacture or by a combination of the gases in proper proportions after their formation.

VI.—In Vapor Burners, in which Benzene of Light Gravity is Used and Burned at the instant it is Vaporized.

The apparatus (of which there is a great variety of forms) consists of a small reservoir containing benzene of a gravity

known in the market as "store oil" (73° to 75° B.). From this reservoir depends a tube conducting the fluid to the extremity of the arm, where the burner is situated. This arm, or at least the portion near the burner, contains a cotton wick, which completely fills the bore of the tube. This cotton cord serves the double purpose of permitting an adequate flow of benzene to maintain the flame, at the same time it prevents a too rapid flow. Immediately around the orifice of the burner is a small depression or cavity, into which is poured about a fluid drachm of benzene which is set fire to. This flame heats the adjacent iron burner sufficiently to vaporize the benzene contained in the tube. The gas is then projected in a stream which burns with a brilliant flame until the contents of the reservoir is exhausted. This form of burner is admirably adapted to street lights in small towns not provided with coal gas.

CHAPTER XIII.

PETROLEUM AS FUEL.

THE use of petroleum in one or other of its varied forms as fuel is traceable to the remotest antiquity. Its combustible nature, with its heat-producing and light-bearing properties, very early attracted the notice of even the most barbarous and uncivilized nations. Its scientific adaptation to numerous practical uses, in accordance with its chemical composition, belongs to modern times. During the last twenty years a great deal of attention has been paid to the subject, resulting in many valuable inventions which have been reduced to practice. The prolific outflow of petroleum from the wells of Western Pennsylvania has been the occasion, in this country at least, of this increased attention to the subject. It did not require a very prolonged course of experiments to demonstrate its entire practicability and its immense advantages in some respects over any form of solid fuel. The question of its employment in this country in competition with our abundant coal supply is yet engaging the minds of some of our acutest inventors. So far, however, the general verdict is where the *economy of fuel is alone* to be considered, petroleum must take a second place. It is true that when economy of space for storage of fuel and convenience of

handling it are to be considered, no fuel can be placed in competition with it. These two considerations are essential factors in determining its use. Where the cost of fuel is not so important as its convenient use, appliances for the use of the liquid fuel will be in demand. On the other hand, where large supplies of the cheaper coal are accessible, petroleum can have no place at the present relative prices. The statements here made have their verification in the present state of affairs in Southern Russia and on the Caspian and Black Seas, where liquid fuel is universally employed. For some remarks relative to the comparative merits of these two forms of fuel, we refer our readers to the chapter on Russian Petroleum. Accepting the glowing accounts of the universal adoption of the "liquid fuel" in that part of the world, on sea-going steamers, on locomotives, for stationary engines, we would be led to suppose the problem of the use of petroleum as a fuel was settled. For that locality it is settled, and petroleum will continue to be so used as long as the existing relation between the prices of coal and petroleum is maintained. Very exhaustive and costly experiments have been conducted under the authority of at least three national commissions, organized for the special purpose of investigating the practicability of introducing its use as a fuel particularly under marine boilers. In each case the report was adverse to such employment, chiefly on the ground of the increased cost. Each report, however, speaks highly of petroleum as a fuel, and grants there may be circumstances under which the increased cost would not be a valid objection to its employ-

ment. M. Sainte Claire Deville made an examination of the subject at the instigation of the Emperor Napoleon. The results of this investigation were published in the Journal of the French Academy of Sciences for the years 1868 and 1869. These papers contain full particulars of his analyses of the different oils employed, together with drawings of the furnaces by means of which the oil was burned. Experiments were made both upon locomotive and marine boilers. He was obliged to report that, at the price at which petroleum then stood, it could not advantageously compete with coal. About two years previous to this a similar commission had instituted experiments at Woolwich, England, with a like result. The report was "less favorable than had been anticipated." The report of Chief Engineer Isherwood, of our navy, while bearing the highest testimony to the fuel value of petroleum, failed to recommend its use or the alteration of the furnaces of our naval vessels for its employment. Now, while these reports were valuable in shaping the policy of these different governments regarding the employment of certain forms of fuel at the time the examination was made, it is not to be supposed they have settled this question for all time. The careful chemical analyses, made in each country, of the fuel employed, and the fact that the calorific power of petroleum was ascertained here, formed a valuable starting-point for those who have followed the same line of study. Since that time in each country the prices of the two kinds of fuels experimented upon have relatively changed; coal has advanced; petroleum has declined. Besides, with sounder

views respecting the true theory of combustion, inventors have still further bridged over the difficulties and once more the very low prices of the liquid fuel invite renewed attention to the subject of its employment as a substitute for coal, particularly under marine boilers and locomotives. From the experiments made under the circumstances just detailed and from a large number made since, the following results can be relied on:—

1. That the calorific power of petroleum for the purposes of generating steam and the evaporation of water is several times greater than that of ordinary coal.

2. That where the price of petroleum does not greatly exceed that of coal, the former will be surely selected for all ordinary purposes of fuel, both for the generation of steam and for furnace operations, especially when any high degree of heat is essential.

3. That illuminating gas of a quality far superior to that of coal can be made from petroleum.

The foregoing observations will be the better understood by stating briefly and simply the theory of combustion. The combustion of any fuel is the combination of its respective combustible elements with their due proportions of oxygen. Hence the first step in determining the value of any fuel, is to ascertain with precision its chemical composition. Those substances known as fuel generally consist of carbon, hydrogen, and oxygen. The two best known varieties of coal are the bituminous or soft coal, the anthracite or hard coal. The other fuels are wood and hydro-carbon oils, of which petroleum is the best and most

abundant representative. Now, perfect combustion is obtained when one part by weight of carbon combines with two and two-thirds parts of oxygen, forming carbonic acid, or when one part by weight of hydrogen unites with eight parts by weight of oxygen, and forms water.

Wood contains carbon, hydrogen, and oxygen, the two latter in proportions to form water; they do not exist as water but simply as stated in the proportion to form water. Wood also contains a large percentage of water which must be driven off by heating before any act of combustion takes place. The proportion of oxygen it contains lessens its value as a fuel, as oxygen is not combustible but is simply a supporter of combustion. Now, having obtained the relative percentages of the combustible materials in each, we find that each of these kinds of fuel will theoretically produce a certain amount of heat, which is expressed by the term "units." A "unit of heat" is that quantity of heat which is necessary to raise one pound of water, one degree of heat Fahrenheit's scale. Based, therefore, upon the calculated percentages of the combustible elements of these different kinds of fuel we are able to estimate accurately their calorific power.

Having these results, and having the relative prices of these different kinds of fuel, and supposing that a fair approximation may be had (by proper regulation of drafts, and adaptation of furnaces) to theoretical results, it is a very simple question to determine their relative and real value as fuel. It is particularly desirable that the question should be fairly stated; much capital has been hopelessly

wasted in endeavoring to prove—what? not that petroleum is a valuable fuel—that is conceded by everybody; weight for weight, it is more valuable than the very best coal—but that it can be used so as to compete with coal. The following observations coming from a practical source are so pertinent here and so entirely in accordance with our own statements that we are induced to repeat them here.

"It is perhaps natural that the enormous production of petroleum with the consequent low price per barrel of a substance, which contains no ash worth mentioning, and which by its composition is all combustible, should lead to many attempts to utilize, what is apparently so valuable as a means of heat production. Hence, we have had from time to time prospectus after prospectus of companies which will revolutionize the heat production of the world, and give us heat and light and power at almost no expense.

"Petroleum-burning furnaces for the manufacture of iron: petroleum-burning locomotives, which were to run at a fraction of the present cost of fuel, have claimed the attention of the world for a brief space and then passed into forgetfulness. This man's process and that man's process for utilizing petroleum as a fuel have succeeded in drawing money from the pockets of capitalists, but, as yet, we believe none of the processes or attempts have succeeded in returning any money to the same pockets in the shape of dividends. The only impression these futile attempts have made, seems to have been to convince the

unfortunate stockholders and experimenters that there was something in the problem which they did not yet understand. But why cannot petroleum be used successfully as a fuel in competition with coal, and what are the possibilities as to the use of petroleum for generating steam in locomotives? Why have so many attempts to utilize petroleum as a means of producing heat resulted in a failure? The answer in brief, is because at present prices, the heat-producing power of a dollar's worth of coal is so much in excess of the heat-producing power of a dollar's worth of petroleum, that although coal is very wastefully burned in actual practice, and although the heat generated is very imperfectly utilized, especially in locomotives, yet no one has hitherto succeeded in burning petroleum in such a way as to compete with coal in cost of heat production. In other words, there is actually much more heat-producing power in a dollar's worth of coal than in a dollar's worth of petroleum.

"The following considerations will, we think, make this point clear. Coal may be regarded as a material consisting of combustible and non-combustible substances. The combustible substances in the case of bituminous coal are principally carbon and hydrogen, while the principal non-combustibles are ash and moisture. In the case of anthracite coal, the principal combustible is carbon, and the principal non-combustible is the ash. In the case of petroleum, almost the whole substance is combustible, and consists of carbon and hydrogen. Now a pound of carbon when burned completely to carbonic acid will generate 14,544

heat units, while a pound of hydrogen when completely burned will generate 62,030 heat units. With these data in hand, and knowing how much carbon and hydrogen a hundred pounds of coal or petroleum contain, it is easy to calculate the relative theoretical heat-producing power of the two substances.

"We assume that the percentage composition of bituminous coal is approximately as follows:—

Carbon	85 per cent.
Hydrogen	5 "
Ash, moisture, etc.	10 "

"Also that the percentage composition of anthracite is approximately—

Carbon	93 per cent.
Ash, etc.	7 "

"And that the percentage composition of petroleum is—

Carbon	86 per cent.
Hydrogen	14 "

"From these data it is easy to compute the relative, theoretical, heat-producing power of equal quantities of these three substances. This we find to be as follows, one pound of each being considered:—

	Heat units.
One pound of bituminous coal will produce theoretically	15,465
" anthracite " " " "	13,526
" petroleum " " "	21,192

"If, now, anthracite coal be assumed to cost, to large consumers, $4.50 per ton, and bituminous coal $4.75 per ton, and crude petroleum 7 cents per gallon, which are very near to New York prices at present, it results that

a dollar's worth of each of these three products will be related to each other as follows, petroleum being assumed to weigh $7\frac{1}{2}$ pounds to the gallon:—

One dollar's worth of anthracite coal is	. .	444 pounds.
" " bituminous "	. .	421 "
" " petroleum is .	. .	103 "

"These various weights of the three kinds of fuel, or a dollar's worth of each on the suppositions made above, as to heat-producing power, will develop heat as follows:—

		Heat units.
444 pounds of anthracite coal will give	. .	6,005,544
421 " bituminous " "	. .	6,510,765
103 " petroleum will give .	. .	2,182,776

"Or, in other words, in accordance with these deductions, the theoretical heat-producing power of a dollar's worth of anthracite or bituminous coal at present prices is nearly three times as great as the heat-producing power of the same value of petroleum.

"Here, then, is the reason why so many petroleum-burning schemes have resulted in failure, viz., petroleum does not have in it, in proportion to its cost, the heat-producing power that coal has. It simply is not there, and as long as the present ratio of prices exists, engineers and experimenters who attempt to use petroleum as fuel must remember they have a powerful rival in coal, and that there is in the very nature of the case a disadvantage in petroleum, which is well nigh staggering and which may well cause them to hesitate on the very threshold of the problem.

"The question whether coal will advance in price in the

future and petroleum diminish, we do not discuss any further than to say that well-informed oil men inform us that petroleum cannot be produced at the wells for less than seventy-five cents per barrel, and the difference between that price and the present one in the oil regions is not enough, to hold out very strong encouragement for a diminution in the price of petroleum.

"But imagine petroleum at present an economical fuel in competition with coal at present prices. We must then consider the effect of this new use of petroleum on the supply and the cost. The production of petroleum has been recently pushed to the utmost, and amounts to 30,000,000 barrels (42 gallons each) per year. In heat-producing capacity the above figures show that it requires 193 gallons of petroleum to equal one ton (2000 pounds) of bituminous coal when combustion is perfect, so that the annual production is equal to about 6,500,000 tons of coal for making heat, with whatever addition may be due to the practically more perfect combustion of petroleum, which could hardly be the coal equivalent of more than 8,000,000 tons. This is about one-ninth of the production of coal in the United States in the census year. But the petroleum production is now nearly all absorbed for illumination. If the equivalent of even 2,000,000 tons of coal a year should be required for making steam the price would certainly rise greatly, for this is equal to one-fourth of our exports. And if the petroleum were required as fuel for other purposes than making steam, it would have to compete with the whole 71,000,000 tons of our coal

production. Therefore without an immense increase of production of petroleum it cannot possibly come into general use as a fuel or even for making steam."[1]

It has been customary to attribute the failure of the profitable employment of petroleum, to the faulty construction of the furnaces in which it is used. It has been charged that the liquid fuel has been wastefully consumed. Granting this, it must be remembered, however, that the foregoing calculations are based upon the assumption that both kinds of fuel have been burned without any loss; but supposing great improvements to be made in the construction of petroleum furnaces, so that the waste of heat be reduced to a minimum, we must not lose sight of the fact that improvements are also being constantly made in the combustion of coal. It is now stated upon good authority, that by the conversion of coal into gas before its real work begins, 1200 pounds of coal can be made to do the work of 2000 pounds under the old method of using it.

It must not be supposed, however, from what has been said, that petroleum cannot be profitably employed under certain circumstances. There are varieties of manufactures of glass, chemicals, and even some kinds of iron, where the quality of product is greatly improved by the use of petroleum as a fuel, and where the enhanced value of the manufactured article more than compensates for the difference in the price of the fuel. This avenue should open up to the inventor an abundant field of exploration,

[1] Railroad Gazette.

and to petroleum a wide range of usefulness, large enough, perhaps, from present appearances, to prevent any glut in the oil market.

In the year 1869, Henri St. Claire Deville conducted an exhaustive series of experiments with the end in view of utilizing petroleum as a fuel. We find in the following schedule an interesting record of these, which will supply to the student engaged in this investigation some important data.

Locality of the Oils.[1]	Specific gravity.	Calorific power.
1. Heavy oil from White Oak, West Va.	0.873	10,180
2. Light oil from Burning Springs, West Va.	0.8412	10,223
3. Light oil from Oil Creek, Penna.	0.816	9,963
4. Heavy oil from Ohio	0.887	10,399
5. Heavy oil from Franklin, Penna.	0.886	10,672
6. American petroleum, as offered for sale in Paris, probably from Pennsylvania	0.820	8,771
7. Heavy coal oil from the Paris Gas Assoc.	1.044	8,916
8. Petroleum from Parma	0.786	10,121
9. Oil from Java, Commune Daudang-Slo	0.923	10,831
10. Oil from Java, Commune Tjibodas Fanggap	0.823	9,593
11. Oil from Java, Commune Gogor	0.972	10,183
12. Oil from Bechelbroun, upper Rhine	0.912	9,708
13. Oil from Bechelbroun, crude	0.892	10,020
14. Oil from Schualweiller, lower Rhine	0.861	10,458
15. Oil from East Galicia	0.870	10,005
16. Oil from West Galicia	0.885	10,231
17. Raw schist oil from Vagnas	0.911	9,046
18. Raw schist oil from Autun	0.870	9,950
19. Heavy oil from Mount de Marjan	0.985	10,081

The same experimenter in 1871 examined four specimens of petroleum from the vicinity of Baku on the borders of the

[1] Compt. Rendus, lxvi. 442; lxviii. 349, C. N. 1869, 237.

Caspian Sea, to which we have alluded in another chapter. We have collected the memoranda and placed them in tabular form. It will be observed that the statements which we have made respecting the superior calorific power of the Russian petroleum are substantiated by these experiments.

Analysis of Russian Petroleum.

	H.	C.	O.	Specific gravity.	Calorific power.
No. 1	12.5	87.4	0.1	0.882	11,370
No. 2	11.7	87.1	1.2	0.928	11,000
No. 3	12.0	86.5	1.5	0.897	11,060
No. 4	13.6	86.9	0.1	0.884	11,660
No. 5	12.8	86.6	1.1	0.938	11,200

There is really no practical difficulty in the way of a much more extensive use of petroleum as fuel, excepting in the matter of cost. For the production of steam, especially in the oil regions, it is largely employed. Here a large amount of waste material, such as coke mixed with residuum "settling" from tanks, is employed for this purpose.

Favre and Silberman give as the result of their calculation the following figures respecting the steam-producing power of petroleum: "One pound of carbon combining with $2\frac{2}{3}$ pounds of oxygen will evaporate 15 pounds of water at 100° C.; one pound of hydrogen combining with 8 pounds of oxygen will evaporate 64.2 pounds of water; and one pound of petroleum consisting of six parts of carbon and one of hydrogen has for its theoretical evapo-

rating power 22.02 pounds. Allowing 20 per cent. of non-combustible matter in anthracite, one pound of it will evaporate theoretically 12 pounds of water; so that one part of petroleum is equal to 1.835 anthracite. A low price for crude petroleum in most markets in America would be four cents per litre, or two cents per pound, or $40 per ton. Average price of anthracite in most markets in America is $8. In some places it is as low as $4, in others $12, but at $8 per ton petroleum would cost for equal heating power about three times as much as anthracite."

Professor S. F. Peckan, in the Tenth Census Report on petroleum, furnishes the following item respecting the steam producing power of petroleum:—

"The oil was burned with a steam jet under four stationary boilers (60 inch shells, 14 feet long with 83.3 inch tubes, and the steam furnished a Worthington compound duplex pump doing an actual work of about 200 horse-power. The indicated horse-power would probably be about 225 or 250). These boilers and this pump use as nearly as possible 4.54 pounds of bituminous coal per horse-power of work done per hour. Using this average, which is pretty well determined as a basis, one ton of 2000 pounds of this coal is equal as fuel to either 3.94 or 4.13 barrels of 42 gallons each of oil. The experiment was not conducted as it should have been, and there is a question as to the pressure against which the pump worked, which accounts for the difference in the estimate. I think it may be stated, however, that four barrels of oil would be re-

quired to furnish the equivalent of a ton of good bituminous coal if the oil is burned with a steam jet. With an air jet I look for better results."

It would be quite useless to multiply the results of similar experiments. It could be easily done, but they all point to the same conclusion, and, moreover, they all verify what could so easily have been predicted from an accurate analysis, and the determination of the actual calorific power from such analysis of petroleum.

As we have before observed we must look for the best results from petroleum, both economically and technically, in those uses where the improved product of the manufactured article more than counterbalances the difference in the price of the two kinds of fuel. We shall not have to go far to find such uses. Even in the manufacture of iron, where the cost of fuel enters very largely into the calculations, there are many conditions where the enhanced value of the product more than compensates for this difference.

At Woolwich, England, in the manufacture of armor-plate for war vessels, most remarkable results have been obtained from the use of the "liquid fuel."

"Under ordinary circumstances the armor-plate bending furnace is lighted from four to five hours before the plate is placed in it. The time occupied in heating the plate for bending depends upon its thickness, one hour per inch of thickness being allowed. Taking then a six-inch plate, we get from ten to eleven hours from the time of starting before the plate is ready for bending. Let us now see what the liquid fuel will do. The cold furnace is lighted, and

after an hour is deemed sufficiently heated. A 6-inch armor-plate, 7 feet 6 inches long by 3 feet wide, is then consigned to the furnace, and after an hour and a half is drawn out thoroughly heated and ready for bending. Thus in two hours and a half we have the work of ten or eleven hours completely and satisfactorily performed. Nor is this all, the advantages of the system do not stop here. The plate is remarkably free from scale, which can only be accounted for by the absence of the deteriorating influence of the products of combustion in the ordinary furnace. Another valuable result arises from this same cause. Thin plates, when heated by liquid fuel and bent double, show no signs of cracking, as they usually do when heated in the coal furnace. This important feature is said to save ten shillings per ton on the metal, which amount it would lose in value by deterioration under the ordinary method of treatment. The fuel, in a vaporized condition, is supplied from the generator to the furnace by six jets, which are led in through small openings, by which means just a sufficient quantity of atmospheric air is admitted to support combustion. This method of supplying the heat also offers another advantage; it can be applied to the whole or any portion of the plate. Thus, if a plate requires to be bent at one end only, then the heat is directed to that part. Further, the rate at which the metal is heated can be regulated to a nicety by increasing or diminishing the number of jets. Close beside the armor-plate furnace is another one for heating thinner ones, which has been regularly at work for some time past. It is heated by four jets, and is

supplied from the same generator which is placed between the two. The average time occupied in heating is seven minutes; with the ordinary furnace, it takes from twelve to fifteen minutes for each plate. In the working of this furnace we have some remarkable results, which must lead us to expect further and even more important improvements in the application of the system.

We have in the records of the results of the operation of an iron furnace at St. Louis, Missouri, an interesting fact brought out, where the increased yield of the product made it profitable to employ petroleum as fuel. The following are the figures:—

No. 1.

Total amount of iron in furnace . . .	pounds	26,378
Amount taken out after being rolled . .	"	24,524
Loss	"	1,854
Loss on same amount of iron in coal furnace .	"	2,901
Thus saving in iron alone by the use of gas	"	1,017
Which at $3\frac{1}{2}$ cents per pound would amount to	.	$36.64
Cost of fuel (gas)	.	42.50
Deduct the saving in iron	.	36.64
Cost remaining	.	5.86
Cost of coal to make the same amount of iron	.	24.52

No. 2.

Iron placed in scrap furnace	pounds	7,950
Taken out	"	7,751
Loss	"	199
Loss, with coal, 15 per cent., or . . .	"	1,192
Deduct loss with gas	"	199
Saving of iron, by use of gas	"	993
Which at $2\frac{1}{2}$ cents per pound would amount to	.	$24.82
Cost of fuel gas	.	$21.25
Saving above cost of fuel	.	$3.57

As to the time necessary to complete the operation it appears that less than one-half of that required by the ordinary method is necessary, and besides, the economy manifested in this instance, the cleanliness and freedom from smoke and cinders are important considerations.

The Eames Process

Has been put in practical operation both in Titusville, Pa., and in Jersey City, opposite New York. I am indebted to Professor Peckham and Professor Wurtz for the following account of it. The diagram is from the United States Census Report of 1880:—

Competent judges having an interest in the success of the establishment at Titusville, bear testimony to the extraordinarily fine quality of the iron produced from scrap and refuse of the most forbidding character. The process has been made the subject of a most careful and exhaustive examination by Professor Henry Wurtz, of New York, and Professor R. H. Thurston, of the Stevens Institute of Technology, Hoboken, New Jersey. The apparatus consists of an ordinary reheating furnace with "generator" and steam-boiler attached.

The generator consists of a cast-iron vessel with alternate projecting shelves attached to its sides. The oil on entering the apparatus trickles over the shelves, from which it is swept by a jet of superheated steam. The amount of oil required for this furnace, which is capable of working charges of 3000 pounds, and making steam for

the rollers besides, is a maximum of 30 gallons, or 200 pounds, per hour. The trickling oil is met by a jet of steam moving in the opposite direction, and is at once completely vaporized under a pressure of about ten pounds, and is carried into an adjoining furnace.

Air subsequently mingles with the steam and oil vapor previously described, and passes the furnace bridge and burns within the furnace and then runs beneath the boilers to the flue and stack.

The old bridge is completely bricked up excepting a space which extends across the furnace closed only by fire-bricks placed on end, and it is found that if this "combustion chamber" has a horizontal thickness of more than eighteen inches the fire-bricks are fused.

Professor Wurtz thus describes the working of this apparatus:—

"It is quite easy to determine with precision with the arrangements at Jersey City the relations of consumption of oil to iron produced, and time, labor, and material occupied in any special case. The oil was fed from a tank, sunk in the ground, which had a horizontal section throughout of four feet square. Each inch in depth, therefore, corresponded to 2304 cubic inches, or closely enough to 10 United States gallons of 231 cubic inches. By gauging with a graduated rod each hour, therefore, the hourly consumption of oil was readily followed up. It was thus determined by me, that, starting with a cold furnace and a boiler full of cold water, 45 minutes was a maximum time, with oil fed at the rate of 30 gallons per

hour, or 22.5 gallons in this time, to bring the whole fire space to a dazzling-white heat. Six piles of boiler scrap averaging 500 pounds, or 3000 pounds in all, being then introduced, 35 minutes more at the same rate of consumption, not only brought the piles to a high melting heat, but raised the steam in the boiler to 90 pounds pressure, being that required to operate the rolls. The time required after the furnace was heated and steam up for each charge of 3000 pounds averaged at most 80 minutes, and as the brickwork became heated throughout, it was apparent the feed of oil might be somewhat diminished. Thus in a working day of 10 hours, just seven such charges could be worked off, averaging 2500 pounds of rolled iron each; total, 8 tons per day of boiler-sheet from one such furnace, with an average consumption as a maximum of 30 gallons (200 pounds) of oil per hour, or 300 gallons (2000 pounds) in all. To this must be added, however, the fuel used under the generator and small supplementary boiler, which together was 500 pounds per day. It is admissible that one generator and one small boiler will operate several furnaces, the inventor says five. If we say four it will diminish the small addendum of cost.

"As to working this furnace with coal, it was ascertained from the testimony of the operators, that by keeping up the fire all night, so that a heat could be had at a reasonable time in the morning, the maximum product of finished sheet might be, with superior work, allowing 90 minutes for each heat, 6 tons, with a consumption of at

least $5\frac{1}{2}$ tons of coal, 12,320 pounds, or 2053 pounds of coal per ton."

Petroleum Stoves and Furnaces for Domestic Purposes and in the Arts.

In the description of these contrivances, which serve a great variety of purposes, we have entered upon what is still considered debatable ground. Where the difference in the price of coal and petroleum is more than compensated for by some superiority of product, or where the cost of handling, or where the superior cleanliness and convenience of petroleum, are in favor of the liquid fuel, we must look for contrivances to meet these conditions. These are not wanting; here American ingenuity, especially during the last decade, has been particularly active in supplying the demand. It would hardly be compatible with the design of this work, to enter with much detail into the specifications of the numerous patents, which have been granted in this department. These naturally fall into one or the other of two classes: one for the consumption of petroleum either refined or crude; the other for burning benzene. On account of their comparative safety, the contrivances of the first class appear to enjoy the most popular favor. For domestic purposes a great variety of stoves, some of them quite pretentious in size and appearance, are already extensively employed. In these, generally, a high-test oil is used. They are mostly employed by small families, and in the summer season when the heat of a large coal-burning

cooking-stove would be almost insupportable. The advantage consists chiefly in the fact, that as soon as the necessity for the stove ceases, the fire is extinguished without any loss of fuel, and as soon as the necessity reappears, the fire is made and in full blast without loss of time: These are two very important desiderata. Besides, we have a positive economy in fuel, to say nothing of superior convenience and cleanliness.

In these stoves ordinary wicks are used, the size of which is proportioned to the amount of heat required. The heat generated is quite sufficient for the ordinary purposes of a small family. To insure safety, it is essential to employ only the best high-test oils.

The other form of stove to which allusion has been made, and which has some advantages, is

The Petroleum Vapor Stove.

The material usually employed in these stoves is benzene, known to the trade as "stove oil," which is benzene of about 75° Baumé, although a naphtha of a higher gravity is frequently used. In this form of apparatus, the fuel, instead of being supplied by capillary attraction through a wick from a fountain beneath the flame, is supplied from a small cistern elevated a few feet above the stove. The benzene flows through a small pipe, and, being heated to the point of vaporization, is, just before it is burnt, commingled with a sufficient quantity of atmospheric air to produce, upon the blowpipe principle, a

powerful heat. This form of stove is furnished with burners of several sizes and of various patterns, many of which are patented, and has a larger range of usefulness than the other, and may be employed not only for domestic purposes but for manufacturers' uses.

Russian Petroleum Locomotives.

Owing to the comparative cheapness of petroleum in the southeastern portion of Russia, especially in the vicinity of Baku, on the Caspian Sea, "liquid fuel" (which is the residuum of the crude oil after the removal by distillation of the burning oil, and which constitutes about sixty per cent. of the ordinary crude oil) is exclusively employed on all the railroads in that vicinity.

The crude petroleum refuse is carried in portable tanks placed upon the tender, these tanks being connected to each other and also to a flexible pipe leading to the engine. The fire-box is fitted with five parallel pipes, which spring from a cross pipe at the rear of the fire-box, this cross pipe receiving a supply of petroleum by the pipe from the tanks on the tender. Below each of the parallel pipes in the fire-box is a corresponding steam pipe, each steam pipe being fitted with four jets and provision made for taking in air to mix with the steam. Each steam jet is surrounded with an annular passage to which the petroleum has access, and it thus injects a spray of petroleum into the fire-box.

In a letter of Mr. Urquhart, addressed to "Engineering," from which the above is drawn, he says: "From fully a

year's experience with petroleum as a fuel on a large scale with passenger and freight engines of various types, I venture to state that petroleum refuse is the best and most convenient form of fuel ever used for locomotives or marine purposes. Space will not admit of enumerating the many advantages this fuel possesses, but a few will suffice to show the saving in time and money which is possible by its use on sea or land, certainly only in countries where it abounds in large quantities and at prices to favorably compare with other forms of fuel. A practicable evaporation of from 12 to 13½ pounds of water per pound of petroleum is quite possible in locomotives under ordinary conditions. A cold locomotive can be fired up to eight atmospheres in from 50 to 55 minutes, and in engines in daily service where the water remains warm, steam can be made to eight atmospheres in from twenty to twenty-five minutes. Water and fuel can be taken at the same time by simply having the water and petroleum tanks or columns conveniently arranged, the latter being required only at engine depôts, say from 100 to 150 miles apart. From three to four tons of petroleum carefully measured can be run into the tank on the tender in about four minutes, requiring the presence of only one fuel attendant. The combustion is smokelessly complete, leaving no soot or other residue in the tubes or furnace. A cast-iron plate, having simply a two-inch sight hole, is fixed over the firing door, thus virtually doing away with the door. The main obstacles hitherto encountered when applying petroleum as a fuel for locomotives, are completely obviated by new and improved appliances, espe-

cially designed for the purpose, a saving of nearly fifty per cent. in weight as compared with coal, being attained in regular practice. Besides for locomotive consumption, petroleum has become quite general as a fuel for pumping and other engines, at the several stations and works on the line."

An objection has been urged against the use of the liquid fuel on account of the danger of fire to the train, especially in case of accident either from collision or running off the track or other cause. Mr. Urquhart disposes of this by furnishing details of an accident where a locomotive and tender loaded with this fuel ran down an embankment dragging with it a train of cars, where no explosion or conflagration took place under these trying circumstances, thus affording some proof of the safety of this kind of fuel. This gentleman has personally superintended the alteration of seventy-two locomotives to fit them for burning petroleum. His *résumé* of the comparative cost of several different kinds of fuel, together with the table from which these comparisons are made, is as follows:—

"Comparing petroleum refuse and anthracite, the former has a theoretical evaporative power of 16.2 pounds of water per pound of fuel, and the latter of 12.2 pounds, at a pressure of 8 atmospheres, or 120 pounds per square inch; hence petroleum has weight for weight 33 per cent. higher evaporative value than anthracite. Now in locomotive practice, a mean evaporation of 7 to 7½ pounds of water per pound of anthracite is about what is generally obtained,

thus giving about 60 per cent. efficiency, while 40 per cent. of the heating power is unavoidably lost. But with petroleum, an evaporation of 12.25 pounds is practically obtained, giving $\frac{12.25}{16.2} =$ 75 per cent. efficiency. Thus, in the first place, petroleum is theoretically 33 superior to anthracite in evaporative power, and secondly, its useful effect is 25 per cent. greater, being 75 per cent. instead of 60 per cent.; while thirdly, weight for weight, the practical evaporative value of petroleum must be recorded as at least from 63 to 75 per cent. higher than that of anthracite.

Petroleum Refuse.—Comparative Trials with Petroleum, Anthracite, Bituminous Coal, and Wood, between Archeda and Tsaritsin on the Grazi and Tsaritsin Railway, in Winter Time.

Date. 1883.	Locomotive.	Train.	Train alone.		Distance run.	Car miles.	Fuel.	Consumption, including lighting up.		Cost of fuel per train mile.	Atmospheric temperature and weather.
			Number of loaded cars.	Gross load.				Total.	Per train mile.		
			No.	Tons.	Miles.					Pence.	
Feb. 8	8	32—23 32—23	25	400	388	9,700	Anthracite.	31,779 lb.	81.90 lb.	11.957	—17° to —18° Reaum., equiv. to —6° to —8½° Fah.
	14	24—21 24—21	25	4ι0	388	9,700	Bituminous coal.	37,557.5 lb.	96.53 lb.	14.093	
	7	26—29	25	400	194	4,850	Petroleum refuse.	9,462 lb.	48.77 lb.	5.487	Strong side wind.
March 6	24	32—23	25	400	194	4,850	Anthracite.	12,639.5 lb.	65.15 lb.	9.512	—5° to —9° Reaum., equiv. to 21° to 12° Fah.
	21	24—21	25	400	194	4,850	Wood, in billets.	1,071.8 c. ft.	5.52 c. ft.	8.5	
	23	26—27	25	400	194	4,850	Petroleum refuse.	7,223 lb.	37.23 lb.	4.188	Light side wind.

Prices of fuel: Petroleum refuse, 21*s.* per ton; anthracite and bituminous coal, 27*s.* 3*d.* per ton; wood, in billets, 42*s.* per cubic sajene = 343 cubic feet; equivalent to 1.47*d.* per cubic foot.

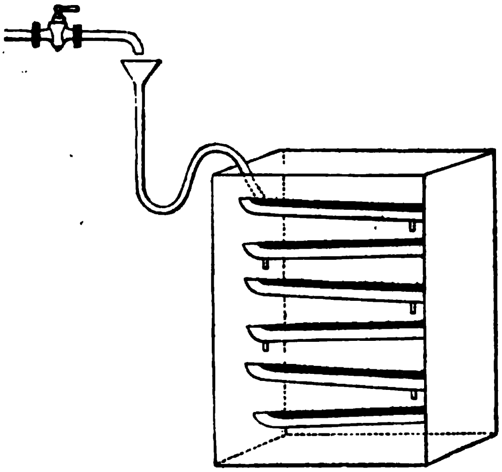
Dimensions of locomotives: Cylinders, 18½ in. diam. and 24 in. stroke; wheels, 4 feet 3 in. diam.; total heating surface, 1248 sq. feet; total adhesion weight, 36 tons; boiler pressure, 8 to 9 atm.

Petroleum under Marine Boilers and Stills.

The first attempts to use the residuum from the distillation of crude oil as fuel were made by Mr. C. Weiser, of Baku, in 1867.

The apparatus constructed and successfully used by him in his factory, consisted of an iron frame bricked in the stoke hole. In this frame were riveted six iron gutters in such a manner, as shown in Fig. 65, that the residuum,

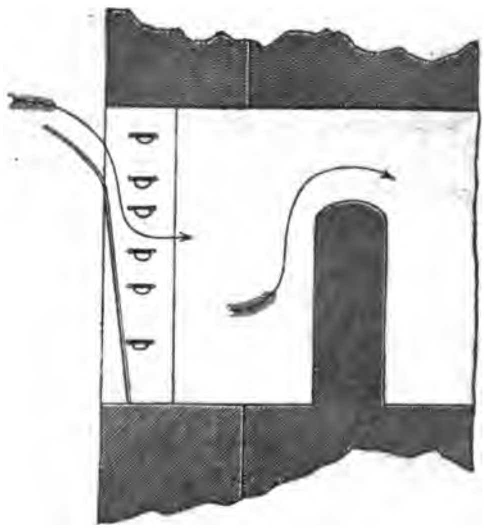
Fig. 65.



which was ignited in the uppermost gutter by means of shavings or tow, had to run from one gutter to another and was thus completely consumed. To burn well, this apparatus requires a strong draft, which is obtained, as shown in Fig. 66, by a movable sheet-iron plate and a bridge of fire-bricks, which divides the flame. This apparatus gives a uniform and very hot flame, but not being

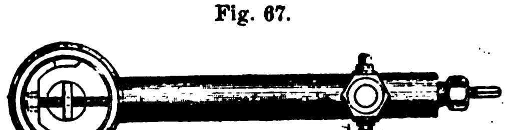
free from soot, is not well adapted for stoves or boilers with narrow fire-tubes.

Fig. 66.



To get rid of the annoyance from soot, Mr. C. Lenz, of Baku, invented, in 1870, an apparatus, called by him "forsunka." The apparatus, which is illustrated by Figs. 67, 67 *a*, is so constructed that a thin jet of steam, which

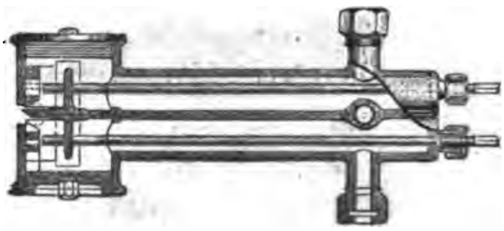
Fig. 67.



meets the petroleum at the mouth of the burning pipe, sprays or atomizes it into a finely divided vapor, and thus effects smokeless combustion. The fan-shaped flame of

Lenz's apparatus was soon changed to a cylindrical form, which was of great importance for boilers with one or two

Fig. 67*a*.



large fire-tubes. For uniformly heating a large surface, Lenz's "forsunka" deserves the preference, and for this reason has been generally introduced in the large refineries in Baku and on board the steamers traversing the Caspian Sea and the River Volga. Based upon a calculation of the heat units of the heavy residuum employed on the steamers, a ton of this should go as far as two tons of coal, but in the best-contrived furnaces a proportion of one to three has often been secured. When it is stated that in Southern Russia one ton of coal costs as much as thirty tons of residuum, the great economy will be at once perceived.

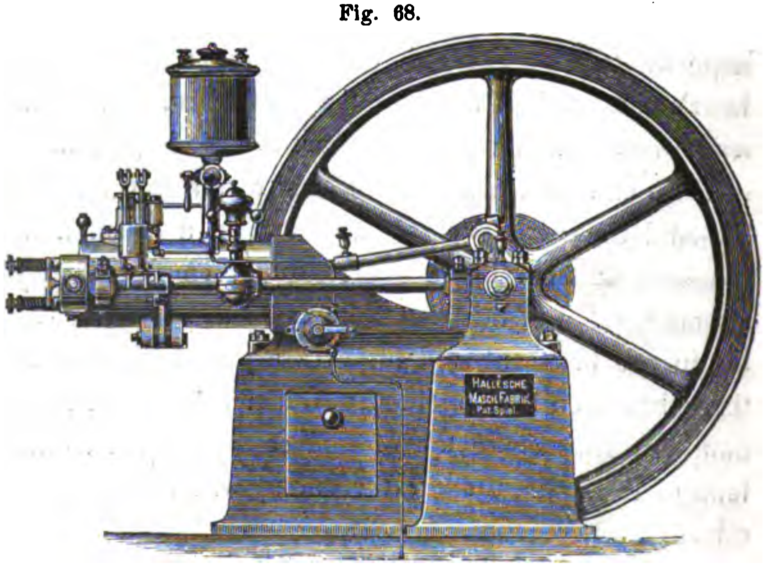
Independent of the economy in the use of petroleum, humanity has been the gainer in this exchange. Few persons can imagine the intolerable sufferings of the unfortunate stokers in the holds of these steamers. The oil is supplied to all the furnaces by a single man by the simple turn of a stop-cock, which is located away from the intense heat. Taking all things into consideration, it is difficult to over-

estimate the advantages accruing to civilization in this part of the world, by the discovery and utilization of the vast deposits of petroleum with which the Caspian region is so abundantly supplied.

PETROLEUM MOTORS.

The petroleum motor (Fig. 68), patented by J. Spiel, and manufactured by the Halle Maschinenfabrik und

Fig. 68.



Eisengiesserei, is in considerable use in Germany, and possesses all the advantages of the gas engine, besides being entirely independent of any coal or gas supply. It can be readily put up anywhere, placed upon wheels, or used for propelling small vessels. There being no smoke, a chimney is not required; the working cost is very small,

and it can be set in motion in a few seconds by simply lighting a small spirit-lamp and turning the fly-wheel. It can be built of all sizes up to fifty horse-power, either as a single or twin engine. When developing its full power the consumption of petroleum for a small engine amounts to about 0.6 kilogr. (1.32 pounds) per horse-power per hour, but to considerably less for large engines. The petroleum can be directly sucked in from the barrel by a pump connected with the engine, or, if the motor is to do a certain duty, for instance, to pump so much water, the required supply of petroleum can be pumped into a reservoir above the engine. In the latter case, the engine requires no attention, as it stops as soon as the supply of petroleum is consumed, and no unnecessary expense is incurred, an important point where the work to be done is intermittent. From the reservoir, the petroleum is conducted by a pipe to the above-mentioned pump, by which small quantities are injected into the cylinder of the engine. The oil is supplied at the rate of four drops per revolution, and, at a given point, is ignited by means of the small spirit-lamp. The *modus operandi* may be briefly explained as follows: On its outstroke the piston draws in a charge of air and petroleum, and on the return stroke it compresses the mixture, which is exploded as the crank passes the back centre. The combustion and expansion of the charge take place at the third stroke, the products of combustion being driven out at the fourth stroke. There is thus one actuating stroke in every four, motion being continued during the other three by means of the fly-wheel. Vapori-

zation or gasification of the petroleum, previous to use, does not take place, the engine using it in its fluid condition. In order to keep the cylinder cool, it is water-jacketed, the water required being taken either from a conduit, or supplied by a pump driven by the motor.

The engine, which has been recently introduced in England, has been thoroughly tested by Mr. John Hopkinson, C. E., who reports upon it very favorably.

The Brayton "hydro-carbon" engine, the invention of Mr. George B. Brayton, at one time was used to some extent in this country. It embodied substantially the same principles as those just described. The claim was made that these engines would develop, with one gallon of crude petroleum, one horse-power for ten hours.

CHAPTER XIV.

TRANSPORTATION OF PETROLEUM.

SOME allusion has already been made to the primitive methods of transporting oil from the wells to the nearest railroad station, or to the most convenient point for shipping on Oil Creek. The business quickly outgrew this mode. The railroad soon entered the oil region, following the tortuous windings of this tributary of the Allegheny River. At first the barrels of oil were placed on platform cars; subsequently two large wooden tanks, holding about 2000 gallons each. In the meantime water transportation had assumed large proportions, quite too large for the volume of water usually flowing in this stream, and the novel expedient of "pond freshets" was resorted to, to which allusion is made in the following terms, in Henry's early and later 'History of Petroleum.'

Arrangements were made with the mill owners at the head of Oil Creek for the use of their surplus water at stated intervals. The boats were towed up the creek by horses, not by a tow-path, but through the stream, to the various points of loading, and when laden they were floated off on a pond freshet. As many as 40,000 barrels were brought out of the creek on one of these freshets, but the average was between 15,000 and 20,000. At Oil City, the

oil was transferred to larger boats. At one time over 1000 boats, 30 steamers, and about 4000 men were engaged in this traffic. At times, great loss occurred from collisions and jams. During the freshet of May, 1864, a "jam" occurred at Oil City, resulting in the loss of from 20,000 to 30,000 barrels. Bulk-barges were subsequently introduced, having a number of water-tight compartments. A few of these are still employed in the conveyance of oil to the refineries situated at Mingo, Wheeling, Marietta, and Parkersburg.

In 1871 the wooden tanks began to disappear, their place being supplied by the horizontal boiler-iron cylindrical tanks now in general use. These will contain from 3000 to 5000 gallons each.

Pipe-Lines.[1]

The greatest revolution, however, in the mode of transporting petroleum, occurred when the idea of allowing it to flow from place to place through iron pipes took a practicable shape. The first experiment of this kind, of which I can find any record, was made by a Mr. Hutchinson, and a pipe-line of three miles in extent was laid from the Sherman well to the terminus of the railroad at Miller's farm. For the purpose of equalizing the pressure and to prevent the bursting of the pipe, he placed at intervals of 50 or 100

[1] The publishers here beg to acknowledge their indebtedness to Mr. Alfred L. Snell, of 'The Petroleum Age,' Bradford, Pa., for most of the matter regarding pipe-lines., etc., comprised in the following pages.—H. C. B.

feet projecting air-chambers about 10 inches in diameter. It is said, however, the weak points of this pipe-line were the jointings, and the leakage was so excessive that little, if any, oil reached the terminus. Shortly afterward, however, mechanical ingenuity proved itself adequate to overcome these obstacles, and a successful pipe-line of four miles was laid, extending from Pithole to Miller's farm. This soon disclosed the superior economy of this mode of transportation, and sounded the death-knell of a once profitable business to the thousand teamsters, who, quickly comprehending the situation, resorted to violent measures to destroy the pipe-line and fire the oil-tanks associated with it. Capital, leagued with an armed police, soon found effective methods to quell riotous opposition, and, shortly afterwards, these lines were ramifying the oil-producing territory. At present, trunk-lines of pipe, six inches in diameter, traverse nearly the whole length of the two great States of New York and Pennsylvania, and cover also portions of the adjoining States, delivering thousands of barrels of oil daily to refineries on the route, and at their different termini on the seaboard.

The wells are connected with the trunk-lines by a 2-inch pipe. The oil is first received into tanks at the wells. On the main trunk-lines are placed, at convenient distances, storage tanks, pumping stations, and racks for loading oil from pipe-lines into tank-cars.

"The pumping stations are located at central points in the valleys. These stations consist of permanent buildings, a boiler-house and a pump-house, which contain the

necessary steam power, and a steam and oil pump combined in one. Many of these pumps are of the Worthington pattern, and are very powerful machines, forcing the oil rapidly through great distances and in vast quantities, not only over the hills that are encountered in the course of the line, but against the friction of the pipe conveying the oil; an element in the problem of vast importance, when it is remembered that the friction increases enormously as the rapidity of flow of the oil is increased. The friction on the 108 miles of six-inch pipe between Rixford and Williamsport, Pennsylvania, is found to be equal to a column of oil 700 feet in height; that is to say, if the pipe were laid on a uniform descending grade of 700 feet between the two points and filled with oil, the friction or the adhesion between the oil and iron would prevent the oil from flowing. For these reasons, the pressure carried on these pumps is frequently from 1200 to 1500 pounds to the square inch." The pipes—the main trunk-line pipes—are constructed to withstand a pressure of 2000 pounds to the square inch. The following process describes the method of loading the tank cars:—

"The 'racks' are used for loading oil from pipe-lines into tank-cars, and are so arranged, that any number of cars from one to an entire train can be loaded at the same time. They are constructed after the following general plan: The line is brought alongside the railroad track, and perpendicular branches are brought up just as far apart as the length of the tank-car. A platform of a convenient height is erected, and each perpendicular branch-

pipe is provided with a stop-cock and an elbow above it. To this elbow is attached an adjustable pipe, long enough to reach the man-hole of the tank-car, as it stands upon the track. To load a train, it is run upon the track in front of the 'rack,' the man-hole plates are all removed, the adjustable pipes placed in position to discharge the oil into the tanks, and the oil turned on. In this way as many cars as the rack will hold, perhaps 20, holding 2000 barrels of oil, can be loaded in an hour and a half."

The storage tanks, the largest of which contain 35,000 barrels of 42 gallons, are built of iron. The roof covering them is of wood, conical in shape, and covered with No. 20 iron.

Few people outside of the oil regions have an adequate conception of the labor involved, the capital engaged, and the business energy displayed in the storage and transportation of crude petroleum, as it is brought forth from its hidden recesses in the earth's crust and delivered over to the manufacturers of the refined product. The owner of an oil well is in direct communication with a freight carrier and a market at all seasons of the year. No sooner has he produced a hundred barrels of oil than, by proper notification, his tank is measured, its contents removed from his sight, and a receipt given him for the amount, which is instantly convertible into cash at the ruling market price.

The United Pipe-Lines, controlled by the Standard Oil Co., is the principal corporation engaged in running oil from the wells, through pipes, to the immense storage reser-

voirs, where it is held until delivered to buyers. As a matter of fact, the process of taking the oil from the tanks of the producers to the tanks of the company, and thence delivering it to the railroads, or the seaboard pipe-lines, for shipment to the remote refining and exporting points, is a constant one.

The other corporations which are engaged in the business are the Tidewater Pipe Co., Limited; the Excelsior Pipe Co. of Oil City; the Pittsburgh Pipe Line; the Southwest Pennsylvania Pipe Lines; the Octave Oil Co. of Titusville; the Franklin Pipe Company, Limited; the Producer's Pipe Line Co. of Franklin; the Macksburg Pipe Line Co. of Macksburg, Ohio; the Marietta Pipe Line of Macksburg, Ohio; the Buckeye Pipe Line of Lima, Ohio, and the Findlay Pipe Line of Findlay, Ohio.

The National Transit and Tidewater Lines are the only lines that issue certificates.

Every thousand barrels of oil in the possession of the pipe-lines, with the exception of the amount necessarily kept on hand to offset evaporation, waste, etc., is represented by an acceptance or "credit balance." These acceptances or certificates are payable on demand, in crude oil, at any shipping point within the oil regions. They are subject to pipeage charges of twenty cents per barrel, when the oil is delivered to a purchaser, and to storage charges of forty cents per thousand barrels for every day the oil remains in the company's tanks. The company is never a holder of oil on its own account, but simply acts in the capacity of a common carrier between the oil producers

and the refiners. These certificates have acquired a speculative value, and exchanges in various cities are entirely devoted to their purchase and sale.

The other lines mentioned above, merely hold the oil to the credit of the producer, which is subject to his order, and can be sold to shippers and refiners.

The pipe-line is a natural outgrowth of the petroleum business. It has perfectly solved the problem of oil transportation. The railroad tank car and the shipping rack, though still in use, are now of only secondary importance. The Oil Creek teamster with his jaded horses and load of wooden barrels, dragging the crude petroleum over mountain roads and down muddy hillsides, from the wells to the Allegheny River flat-boat, or to the nearest railroad station, is no longer a familiar object in oil-region scenery. His occupation ceased with the advent of the massive steam pump and the huge cistern of boiler-iron.

The United Pipe Lines' Association, first known as the Fairview Pipe Line, was organized by Capt. J. J. Vandergrift and George V. Forman. It is incorporated under the provisions of the general Act of the Pennsylvania Legislature of the 29th of April, 1874. It commenced business on a comparatively small scale, and at a time when there were numerous lines in existence, all actively engaged in a ruinous competition. The new company endeavored to avoid this suicidal policy, and was successful.

Other lines were merged with it from time to time, until it became the rich and powerful organization of the present day. The lines that have been bought and consolidated

with the United since 1877, are the Antwerp, Oil City, Clarion, Union, Conduit, Karns, Grant, Pennsylvania, Relief, the Clarion and McKean divisions of the American Transfer Co., the Prentiss Lines, the Olean Pipe, the Union Oil Co.'s Line at Clarendon, and the McCalmont Line in Cherry Grove.

The United Pipe Lines cover the oil regions from Allegany to Butler, with a network of iron through which the wealth of the country continually pulsates. Its only competitor of importance, at the present day, is the Tidewater Pipe Line, a much smaller organization, but a persistent and energetic rival. The United Lines own 3000 miles of iron pipe, and control a storage capacity of 40,000,000 barrels. With its present force it can remove 80,000 barrels of oil from the producers' tanks in a single day, and place it where it can be taken out of the regions. One hundred and thirty-five pumping stations are required to do the work of transferring oil from one part of the field to another. These stations range from the smallest boiler and engine, in a rude hut, in some remote section, to the nicely fitted buildings containing from one to five seventy-horse-power boilers, with engines and pumps of commensurate magnitude. The largest of these stations are at Tarport, Duke Centre, Richburg, and Kane. Of the entire number, 43 are located in the Bradford and Allegany fields, 32 in the Warren and Forest, and 60 in the Lower Country. The United Pipe Lines employ 57 gaugers in Bradford and Allegany, and 50 in the other portions of the field. The chief offices are at Bradford and Oil City, and each

station is connected by telegraph with one or the other of the main offices. The employés at the pump stations are required to be telegraph operators as well as engineers. When a gauger measures up the tank of a producer and the oil is passed into the pipe-line, the report is wired to the central point of that section of the field. Here, accurately prepared tables, representing the measurements of every producer's tank in the region, are at hand, properly labelled and numbered. A reference to the right table shows at a glance the amount of oil in barrels that corresponds to the feet and inches run as reported by the gauger, and this amount is immediately credited to the producer on the books of the Pipe Line office. These reports are carefully summed up, and the company knows exactly how much oil has been received, and the total amount under its control at the beginning and close of each day. This system involves a vast amount of book-keeping, and requires a large clerical force of expert accountants and telegraph operators. An ingenious method of checking results has been devised, and so systematic and well-regulated is everything connected with the business, that any carelessness or dishonesty on the part of employés, that may result in waste or loss of oil, can be promptly traced to the proper source and corrected.

The business plant of the United Pipe Lines was formally transferred to the National Transit Company on April 1st, 1884, but there has been little change in the officers of the company.

THE NATIONAL TRANSIT COMPANY.

The National Transit Company is the organization engaged in the transportation of oil from the regions to the seaboard and the interior refineries. It takes the producers' oil from the tanks of the pipe-lines and delivers it to the New York, Philadelphia, and Baltimore exporters and refiners, and the manufacturers of illuminating oil at Pittsburgh, Cleveland, and Buffalo. This company received its charter at the hands of the Pennsylvania Legislature. It holds the original charter granted to Andrew Howard, J. S. Swartz, and others, under the name of the "Pennsylvania Company," by the Act of April 7th, 1870. Six years ago it absorbed the business and plant of the American Transfer Company, a corporation engaged in the same business.

The approximate cost of its property was $15,000,000. It owns 15,000,000 barrels of iron tankage and several thousand miles of iron pipes, besides pump stations, machine shops, etc. Its six lines of pipe connect the oil regions with the sea-shore and the refineries at New York, Philadelphia, and Baltimore, and with the interior refineries at Pittsburgh, Cleveland, and Buffalo.

The New York division consists of two six-inch pipe-lines from Olean, N. Y., to Saddle River, N. J., where it branches, one line sixteen miles in length going to Bayonne, N. J., on New York Bay, and the other, twelve miles long, crossing the Hudson River, extending through the heart of New York City, and thence across the East River, to the great refineries at Hunter's Point, on Long Island.

The Bayonne branch consists of two, while the Hunter's Point has but one line of six-inch pipe. A diver is kept constantly employed to repair any damages to the line that may be caused by the numerous vessels in the waterways about New York.

A third six-inch line has been laid from Wellsville to Cameron's Mills, but at present is used only for the conveyance of natural gas to the boilers at that station. The New York division is over three hundred miles long, and has eleven pumping stations, located at the following places:—

Olean to—		Distance, miles.
Wellsville		28.24
Cameron's Mills		27.92
West Junction		29.74
Catatunk		27.43
Osborn Hollow		27.98
Hancock		29.83
Cochecton		26.23
Swartwout		28.93
Newfoundland		29.00
Saddle River to		28.78
Terminal Stations	Bayonne, N. J.	16.29
	Hunter's Point, N. Y.	12.26
	Total	312.63

Each station is provided with seven or eight boilers of from 80 to 100 horse-power, and two large Worthington pumping engines. The boilers are in brick houses, each forty feet square and covered with roofs of corrugated iron. The pumps are in separate buildings of the same class as the boiler houses. There are two or more 35,000-barrel

iron tanks at each station, with the exception of Cochecton, where there is but one, and a telegraph office with all the latest electrical appliances. For lighting the stations, the Edison incandescent system is employed. The oil is kept moving from one station to another, where it is received into a huge iron reservoir and immediately forced forward on its journey to the seaboard. The extra tankage is used mainly for storage. At Cameron's Mills, there are four iron tanks, and at Saddle River, thirteen. The stations are all connected by a line of telegraph, and each one is manned by two firemen and two telegraph operators, a double force for day and night work. There is no cessation to the work of pumping the oil, except in case of breakage or leakage. The stream of oil is kept moving onward every day and night of the year.

The course of the lines is through the southern tier of counties in New York State: Cattaraugus, Allegany, Steuben, Chemung, Tioga, Broome, Delaware, Sullivan, and Orange, and across the northern part of New Jersey, through Sussex, Morris, Passaic, Bergen, and Hudson counties. The pipes are buried at a depth of two or three feet, and follow the general contour of the country through which they pass. They climb up the steepest ascents, and descend into the valleys, turning aside for neither mountains nor rivers. They cross beautiful farms, wind through pleasant little towns and villages, and traverse wild forests and tangled swamps. At New York, a single line burrows in the muddy bottom of the "majestic Hudson" and finds a passage through Gotham's far-famed Central Park.

The Pennsylvania division is two hundred and thirty-five miles long, and has but a single six-inch pipe, which extends from Colegrove, in McKean County, to Philadelphia. There are six pumping stations on this line, viz: Colegrove, Hunt's Run, North Point, Pine, Latshaw, and Millway. A branch pipe extends from this line to Milton, Pa., where tank cars can be loaded for Philadelphia on the P. & E. R. R.

The stations, with their distances from each other, in miles are given below:—

Colegrove to—	Miles.
Hunt's Run	23.41
North Point	25.90
Pine	25.73
Latshaw	45.40
Millway	51.92
To Philadelphia, terminus	62.52
Total, Colegrove to Philadelphia	234.88

The Baltimore division consists of 65.81 miles of five-inch pipe, connecting Baltimore with the Philadelphia division, at Millway. One pump station is sufficient for this line, and it is located at the last-named place.

The Cleveland line begins at Bear Creek, in Clarion County, and ends at Cleveland. It is of five-inch pipe and one hundred miles in length. There are five stations on this line, Bear Creek, Hilliards, Mercer, Warren, and Mantua, which are situated as follows, with distances:—

Bear Creek to—	Miles.
Hilliards (6-inch line)	8.51
Mercer (5-inch line)	24.62
Warren, O. "	27.46
Mantua, O. "	22.16
To Cleveland (5-inch line)	28.59
From Hilliards to Cleveland	102.83

The Buffalo division is about sixty-three miles in length, and consists of one four-inch pipe, with its initial station at Four Mile, Cattaraugus County, N. Y. There is another station at Ashford and one at the terminus of the line in Buffalo.

The Pittsburgh line is 38.81 miles long, and extends from Carbon Centre, in Butler County, to Brilliant, a suburb of Pittsburgh. There are connecting lines between Carbon Centre, and Bear Creek, and Hilliards.

When the pipes become obstructed in any manner, clogged by paraffine, or from any other cause refuse to work freely, a small instrument, which is known as a "scraper," is inserted. This is made of iron about two feet in length, and consists of two parts united by a socket-joint. In front are four arms, with small wheels at the ends, which are forced against the interior of the pipes by springs. A set of steel knives, arranged like the wings of a wind-mill, are attached to the shaft, and the pressure from the pumps causes these knives to revolve, and forces the whole machine forward through the line from station to station. Two men, generally, follow along the line, with a horse and carriage keeping within hearing of the "scraper" which makes a peculiar whirring noise as it is

forced through the lines. The double joint enables it to pass around all ordinary curves, and if it becomes fastened from any cause, the pipe must be taken up and the obstruction removed. It is the duty of the men who follow up the scraper, to locate the spot where they ceased to hear its noise, for it is a sure indication that something serious has happened. Under ordinary circumstances the scraper passes rapidly through the lines, cutting off all the sedimentary matter that has adhered to the pipes, and loosening it up, so that it can be pumped into the receiving tank at the nearest station.

The United Pipe Lines.

The United Pipe Lines Division of the National Transit Company, is the name of the organization that receives oil direct from the tanks of the producers and delivers it to the storage reservoirs, from which it is transported to the refiner. It controls most of the subsidiary lines that are laid from well to well, all over the oil country, and its gaugers and other employés come in daily contact with the great body of petroleum producers. It controls two six-inch lines that extend from Kane, in McKean County, to Bear Creek, in Clarion County. The line, after it leaves Bear Creek, is under the charge of the National Transit Company. One of the lines at Kane makes a loop westward to Sheffield, in Warren County, and takes oil from Cooper, Henry's Mills, Balltown, Cherry Grove, and other districts of Warren and Forest counties. Another line is

now being constructed that will extend this system so as to reach the oil territory at Grand Valley in the southwest corner of Warren County. These lines also receive oil from the Bradford field, and from the new oil district near Kane, in the southwestern part of McKean County.

The Bradford field is connected with the large pump stations at Kane, Colegrove, and Olean in the following manner: From Tarport to Olean are two six-inch lines, while one six-inch line leads from Tarport to Tally Ho, where it converges into three four-inch lines that go to Kane. A four-inch line starts at Tarport and runs to Coleville, where it meets a three-inch line from Rixford, and both branch into a six-inch line from Coleville to Colegrove. Oil from the great Bradford district can be sent out of the region through nine pipes, by five routes, viz: *via* Olean to New York; Colegrove to Philadelphia and Baltimore; *via* Kane to Pittsburgh and Cleveland; *via* Rock City to Buffalo; and with Tidewater line, *via* Rixford to Tamanend.

The Tidioute and Titusville branch of the United Pipe Lines receives oil from Tidioute, Grand Valley, and adjacent districts, and delivers at Oil City and Titusville.

The Tidewater Pipe Line, Limited.

The Tidewater stands second to the United Pipe Lines in importance and magnitude. It receives oil from the wells, issues acceptances, certificates, and other vouchers, and transports the oil through a single six-inch line from

Rixford, its principal station in the Bradford field, to Tamanend, in Schuylkill County, its present terminal station. The line is now being continued from Tamanend through Eastern Pennsylvania, and across New Jersey to New York City.

This company was chartered in November, 1878, and it has offices at Titusville, Bradford, Olean, Bolivar, Philadelphia, and New York. Its main offices are at Titusville, while Bradford, New York, and Philadelphia are the offices that issue the certificates. At all the offices the credit balances of the producer are convertible into cash.

The Tidewater Line confines its operations to the Bradford and Allegany fields. In the Bradford field its principal pump stations are at Duke Centre, Moody, Knox, Dallas City, Emery, Custer City, Moody, Indian Creek, and Derrick. From all these points oil is pumped to the main trunk station at Rixford. In the Allegany field, Allentown is the principal point from which the oil is pumped through a four-inch line to Bolivar and Indian Creek stations, and thence to Rixford.

The distance from Rixford to Tamanend is 172 miles, and there are five pumping stations on the line, viz., Rixford in McKean County, Olmstead in Potter County, County Line Springs in Lycoming County, Muncy in Lycoming County (lately abandoned), and Shuman in Columbia County. The Tidewater Pipe Company's telegraph department is complete, and connects Titusville and Bradford with New York and all the stations in its system

of pipe lines. The oil at Tamanend terminus is transferred by tank cars to Bayonne, N. J., and Philadelphia. The miles of pipe owned by the Tidewater Pipe Co. with their capacity, etc., are contained in the following statement:—

Miles of pipe.	Inside diameter.	Capacity per mile.	Total capacity.
$416\frac{74}{100}$	$2\frac{67}{1000}$ inches.	$21\frac{914}{1000}$ barrels.	$9,132\frac{44}{100}$ barrels.
$90\frac{89}{100}$	$3\frac{67}{1000}$ "	$48\frac{247}{1000}$ "	$4,385\frac{17}{100}$ "
$15\frac{70}{100}$	$4\frac{26}{1000}$ "	$83\frac{137}{1000}$ "	$1,305\frac{25}{100}$ "
$171\frac{80}{100}$	$6\frac{65}{1000}$ "	$188\frac{672}{1000}$ "	$32,413\frac{85}{100}$ "
$1\frac{86}{100}$	$7\frac{982}{1000}$ "	$326\frac{790}{1000}$ "	$607\frac{82}{100}$ "
$\frac{47}{100}$	$10\frac{19}{1000}$ "	$514\frac{865}{1000}$ "	$241\frac{98}{100}$ "
$\frac{62}{100}$	$12\frac{25}{1000}$ "	$741\frac{677}{1000}$ "	$459\frac{84}{100}$ "

Pittsburgh Pipe Lines.

This line was built by Holdship & Irwin and D. P. Reighard, independent refiners of Pittsburgh in May, 1885, and extends from the wells at Thorn Creek and St. Joe, in Butler County, to the Pittsburgh and Western R. R. at Reibold, where its oil is loaded on the cars and forwarded to Pittsburgh. During the past year it has enlarged its business so as to take oil from the Washington and Shannopin fields. At Washington, the oil was loaded by the line at Ewing station and sent by tank cars to Pittsburgh. At Shannopin a line leads from the wells to the Ohio River, where the oil is transferred to barges and towed by steam tugs to the Smoky City.

The Southwest Pennsylvania Pipe Line.

This line was called into existence by the development of the Washington and Shannopin Oil Districts, in the Southwestern part of the State. It is controlled by the National Transit Co., and consists of a single six-inch line, which extends from Ewing's Station on the Chartiers Valley R. R. in Washington County, through the Shannopin or Shoustown Field in Beaver County, to Carbon Centre in Butler County, where it connects with the main pipes of the National Transit Company.

Minor Pipe Lines.

The Octave Oil Co.'s Pipe Line is controlled almost entirely by David Emery, of Titusville, and extends from the oil wells in the Octave District near Titusville to the refineries at that place. It is only a few miles in length, and handles between three and four thousand barrels of oil a month.

The Excelsior Oil Co. is the name of a recent corporation, that has built a line from the Tarkill Oil Field in Venango County to the refineries on Oil Creek, north of Oil City. It is ten or twelve miles long, and has been the cause of Tarkill producers receiving for their oil a premium of 15 cents per barrel above the market price established by the oil exchanges.

There are two pipe lines in the heavy oil district at Franklin, Pa., one of which is the Producers' Pipe Line

Company, and the other the Franklin Pipe Company, Limited. The business of each is confined to handling heavy oil, which is received from the producers' tanks in this district, and delivered at the loading racks along the railroads that centre at Franklin, and to the large manufactories of lubricating oils at the same place. Neither of the lines is over eight miles in length.

Besides the above there are numerous small lines on producing properties along the railroads at Clarendon, Tiona, Grand Valley, Emlenton, and other points. These do business in shipping oil to the small refineries scattered throughout the region.

The Ohio Pipe Lines.

In the Macksburg, Ohio, oil field there are two pipe lines engaged in the business of transporting oil, the Macksburg Pipe Line, controlled by the National Transit Company, and the Marietta Pipe Line, which is owned principally by George Rice, a heavy producer of Macksburg, and a leading independent refiner of Marietta. The route of Rice's line is from Macksburg to Lowell, on the Muskingum River, a distance of ten miles. At the latter place the oil is loaded on barges, and floated down to Marietta.

In the oil fields of Northwestern Ohio two pipe lines are at present in operation, the Buckeye Pipe Line, of Lima, Ohio, a National Transit Company organization, and the Findlay Pipe Line, of Findlay, Ohio.

The foregoing statements refer more particularly to the

transportation of what are termed "light oils," chiefly employed for refining purposes in the manufacture of illuminating oils. This constitutes, however, the bulk of the trade. The heavier oils used for lubricating purposes, or for the manufacture of lubricating oils, are still largely transported in barrels. The Mecca, West Virginia, Southern Ohio, and the Smith's Ferry are largely handled in this way. The oil is removed in barrels from the wells, dumped into a tank at the nearest railroad station, and loaded thence into tank-cars. The Western Virginia Transportation Company (pipe-line), divide its heavy oils into several grades, gives receipts for the oil according to gravity, and delivers to the customers at the various termini of its lines an oil of similar quality. The charges for transportation are consequently higher.

APPENDIX.

THE PRODUCT AND EXHAUSTION OF THE OIL REGIONS OF PENNSYLVANIA AND NEW YORK.[1]

BY

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THE Petroleum industry of Western Pennsylvania and South-western New York has been one of phenomenal development. Greater and more sudden fluctuations have occurred in the price[2] of crude oil, and in all the collateral interests, dependent upon its production, than in the case of any other mineral product which has been extensively exploited in the United States. This was particularly the case from the commencement of drilling for oil in 1859, down to the end of 1877. The experience gained during these early years has enabled the oil men to operate more intelligently, and the business is not now attended with the hazardous risks with which it is generally credited.

The most important questions connected with the oil industry. are those of (*a*) the oil supply, and of (*b*) the possible ultimate exhaustion of the field. Since 1876, my attention has been directed to the study of the statistics of the product of the oil regions. In January, 1880, in order to show some interesting points connected with these ques-

[1] Read before the American Institute of Mining Engineers, at the Halifax Meeting, September, 1885.

[2] The average price of crude oil for January, 1863, was ten cents a barrel. This was the lowest monthly average ever attained; the highest monthly average was $12.12½ per barrel for July, 1864. The lowest yearly average was 78¾ cents for 1882, and the highest $9.87½ for 1864. The average price of the entire product to January, 1885 (260,990,435 barrels), has been $1.63½. A barrel of petroleum is always considered to contain forty-two gallons.

tions, I prepared a graphic chart, which was used to illustrate a lecture on petroleum, delivered before the Franklin Institute. This chart was afterwards reconstructed, in two distinct forms, for publication in the census report on *Petroleum and its Products.* I have redrawn these in a condensed form, and have extended them to include the statistics down to 1885, for publication in the *Transactions* of the Institute, in conjunction with a map of the oil regions prepared by Mr. John F. Carll and myself, Plate II. It is hoped that these illustrations will be found interesting to the members of the Institute, and of practical utility to oil men, without any extended discussion, since it is my desire to make only such brief references to them and give such additional details as may serve to make the prominent features comprehensible. (See Figs. 69 and 70.)

During the past few years, the individual oil-pools of the region have been grouped, for convenience of reference, under six prominent districts, as follows:—

1. Allegany district includes the Richburg and several small outlying pools in Allegany County, N. Y. The area which has proved productive oil territory is 31 square miles,[1] of which the Richburg field embraces an area of 28 square miles.

The Allegany district up to January, 1885, produced 15,000,000 barrels, an average of about 419,000 barrels per square mile.

2. Bradford district embraces the oil pools in central and northern McKean County, Pa., and southern Cattaraugus County, N. Y. The area of productive territory in this district is 133 square miles, 121 square miles of which is included within the Bradford field proper. The sand from which the oil in the Allegany and Bradford districts is obtained consists of a gray, black, dark-brown, or chocolate-brown, colored sand of about the coarseness of the ordinary beach-sand of the New Jersey coast.

[1] The territories, of which the areas are given here, were defined by arbitrary lines, drawn to include all the surface where producing wells have been obtained, or, which, down to January, 1885, was known, from actual drilling, to be underlaid with oil. All the individual pools are shown on the accompanying map. The areas of some of them have been slightly exaggerated in order that they might be observed on a scale of twenty-five miles to one inch. A map on a scale of six miles to one inch, showing, with approximate exactness, the areas of the pools, will appear in the annual report of the Second Geological Survey of Pennsylvania for the year 1885. The total area of all the productive oil territory in Pennsylvania, prior to 1885, was 369 square miles.

To

Fig. 69.

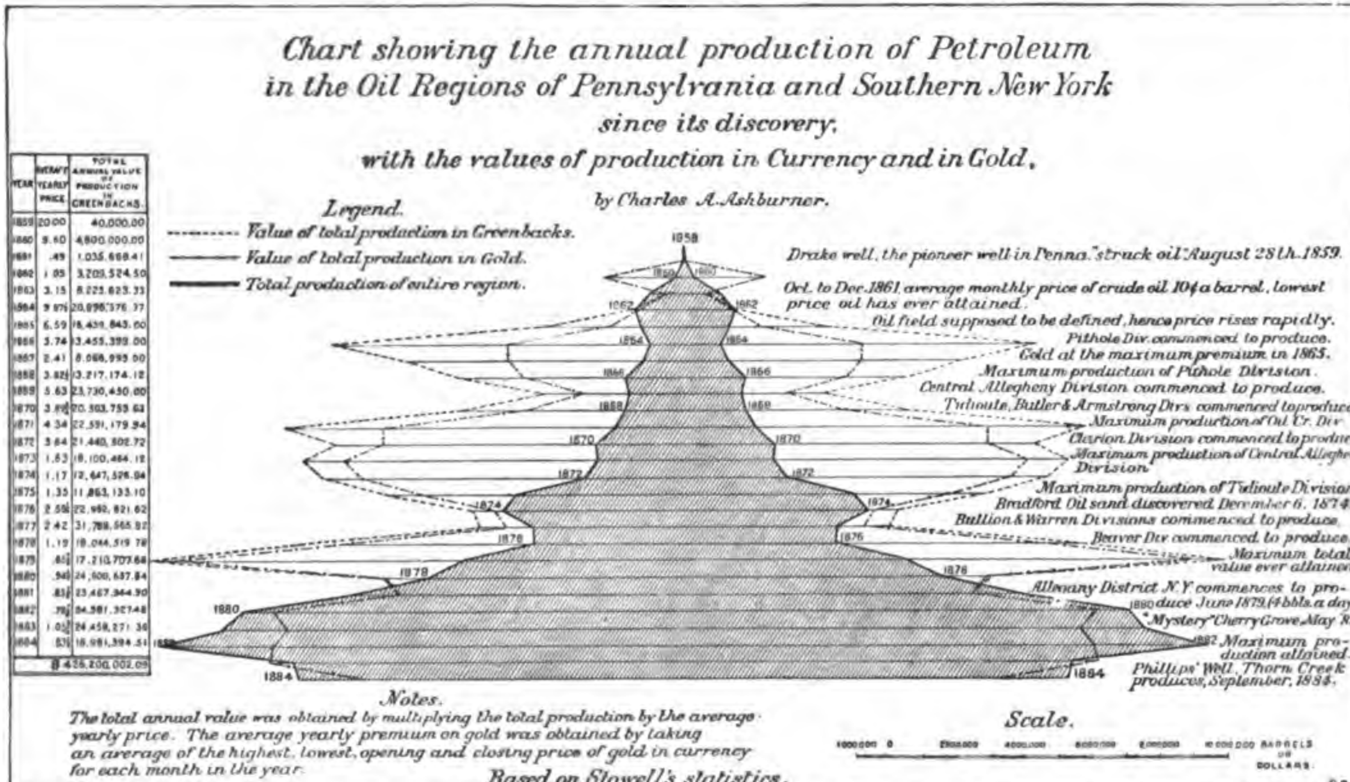
Chart showing the annual production of Petroleum in the Oil Regions of Pennsylvania and Southern New York since its discovery, with the values of production in Currency and in Gold.
by Charles A. Ashburner.
Legend.
Value of total production in Greenbacks.
Value of total production in Gold.
Total production of entire region.
Drake well, the pioneer well in Penna. "struck oil" August 28th. 1859.
Oct. to Dec. 1861, average monthly price of crude oil 10¢ a barrel, lowest price oil has ever attained.
Oil field supposed to be defined, hence price rises rapidly.
Pithole Div. commenced to produce.
Gold at the maximum premium in 1865.
Maximum production of Pithole Division.
Central Allegheny Division commenced to produce.
Tidioute, Butler & Armstrong Divs. commenced to produce.
Maximum production of Oil Cr. Div.
Clarion Division commenced to produce.
Maximum production of Central Allegheny Division.
Maximum production of Tidioute Division.
Bradford Oil sand discovered December 6, 1874.
Bullion & Warren Divisions commenced to produce.
Beaver Div. commenced to produce.
Maximum total value ever attained.
Allegany District N.Y. commences to produce June 1879 (4 bbls. a day).
"Mystery" Cherry Grove May '82.
Maximum production attained.
Phillips' Well, Thorn Creek produces, September, 1884.
Notes.
The total annual value was obtained by multiplying the total production by the average yearly price. The average yearly premium on gold was obtained by taking an average of the highest, lowest, opening and closing price of gold in currency for each month in the year.
Based on Stowell's statistics.
Scale.

The interval between the top of the oil-sand and the bottom of the Olean conglomerate (the lowest member of the Pottsville conglomerate, No. XII., or Millstone grit), which is one of the most persistent and best recognized geological horizons in Western Pennsylvania, is, at Bradford, 1775 feet.

The oil obtained is dark amber-green and occasionally black. Its gravity is generally slightly greater than that of the oil usually obtained throughout the Venango and Butler districts, which is generally stated at about 48 degrees.

The Bradford district, down to January, 1885, produced 109,000,000 barrels; an average of about 820,000 barrels per square mile.

3. The Warren district comprises the oil-pools in eastern Warren County and northeastern Forest County, Pa. The total area of the productive territory in this district is 35 square miles. The two largest pools are the Clarendon, in Warren County, which covers an area of about 14 square miles, and the Cooper and Sheffield, partly in Warren and partly in Forest, which covers an area of 9 square miles.

The oil in this district comes from sands of varying geological horizons, having somewhat the general appearance of the Bradford and Allegany sand, but frequently coarser-grained and sometimes containing small pebbles, which latter I have never known to have been found in the sands of the other two districts. According to Mr. Carll, the depths of the Warren district oil-sands, below the Olean conglomerate, are as follows: North Warren sand, 1100 feet; Warren third sand, 1300 feet; Clarendon third sand, 1450 feet; Cherry Grove third sand, 1625 feet; and Cooper (Forest County) third sand, 1850 feet. The Cooper sand is supposed to occupy the same geological horizon as the Bradford and Allegany sand. The Allegany, Bradford, and Warren district sands I believe to be of Chemung (Devonian) age. The oils from the different Warren pools vary greatly in color and gravity; but they are generally spoken of as amber oils. The Warren district, down to January, 1885, produced 12,000,000 barrels, an average of about 343,000 barrels per square mile.

4. The Venango district, which was the scene of all the earlier oil developments, includes 40 distinct and well-recognized oil-pools, the total area of which is 65 square miles, the largest pool being that lying between Oil City on the south and Pleasantville on the north, which covers an area of 28 square miles. No one of the other pools exceeds an area of 5 square miles, which is about the productive

Fig. 70.

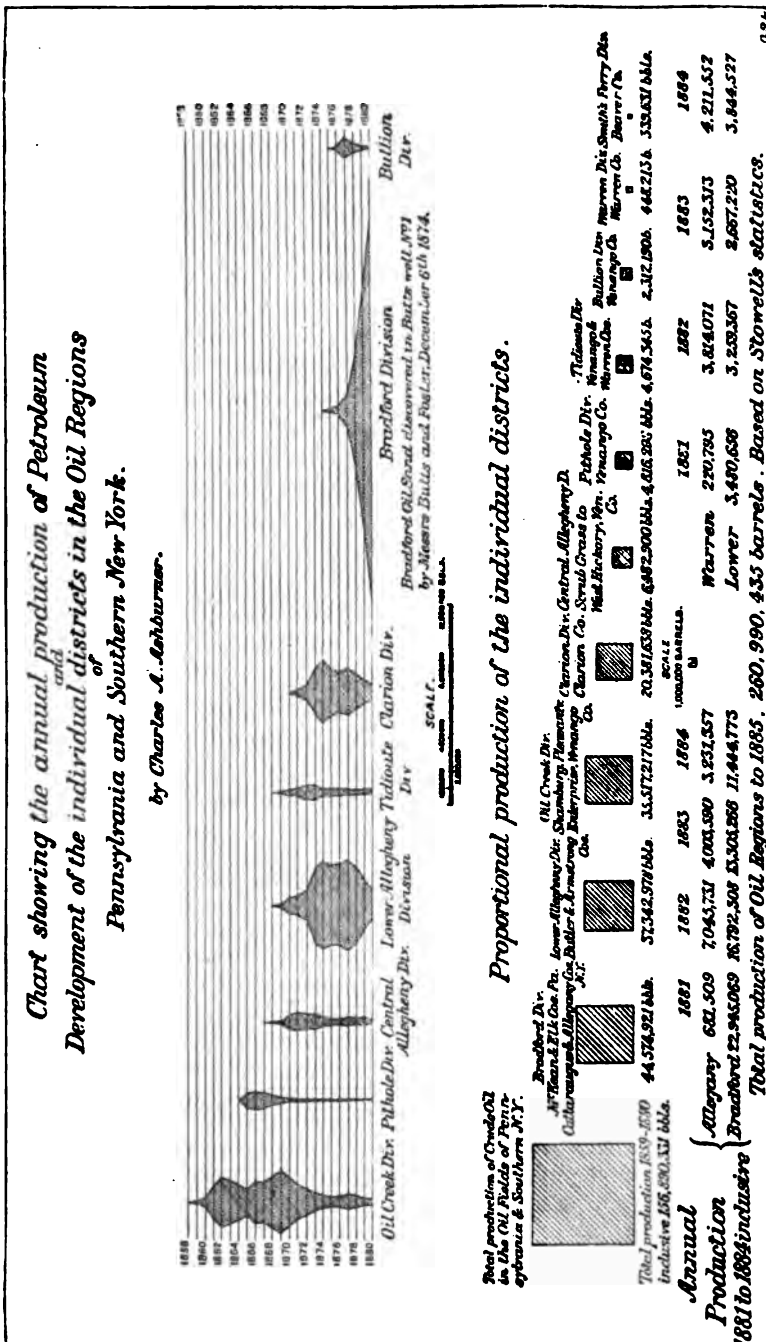
Chart showing the annual production of Petroleum
and
Development of the individual districts in the Oil Regions
of
Pennsylvania and Southern New York.
by Charles A. Ashburner.
Oil Creek Div.
Pithole Div.
Central Allegheny Div.
Lower Allegheny Division
Tidioute Div.
Clarion Div.
Bradford Division
Bullion Div.
Bradford Oil Sand discovered in Butts well No 1 by Messrs Butts and Foster, December 6th 1874.
SCALE
Proportional production of the individual districts.
Total production of Crude Oil in the Oil Fields of Pennsylvania & Southern N.Y.
Total production 1859-1880 inclusive 156,890,521 bbls.
44,576,921 bbls.
57,342,978 bbls.
33,571,217 bbls.
20,381,638 bbls.
6,482,900 bbls.
4,616,395 bbls.
4,674,345 b.
2,312,190 b.
448,213 b.
339,631 bbls.
Annual Production 1881 to 1884 inclusive
1881 1882 1883 1884
Allegany 682,509 7,045,731 4,003,590 3,232,357
Bradford 22,945,069 16,792,308 13,306,268 11,444,773
1881 1882 1883 1884
Warren 220,795 3,814,071 5,152,313 4,211,552
Lower 3,480,636 3,259,367 2,667,220 3,844,527
Total production of Oil Regions to 1885. 260,990,435 barrels. Based on Stowell's statistics.

territory covered by the Tidioute and Triumph pool in southwestern Warren County, and the Franklin pool in western Venango County. The oil of this district is obtained from three principal sand-beds, contained within an interval of 350 feet, and known, respectively, as the first, second, and third oil-sands. The first sand, which is the uppermost one of the three, lies about 450 feet below the base of the Olean conglomerate. I believe that the Venango sands belong to the Catskill (Devonian) formation No. IX. These oil-sands were the first discovered in Pennsylvania; and drillers from this field, operating in other districts, have designated the sands which were found in the new districts as the first, second, and third sands, irrespective of their relative geological position. The Venango sands generally consist of a white, gray, or yellow pebble-rock. The pebbles are water-worn, are sometimes as large as hazel-nuts, and are loosely cemented together, and generally bedded in fine sand. The sand in this district is not as regular, or as homogeneous, over extended areas, as in the Bradford and Allegany fields, where the sands are phenomenal in this respect; consequently, the risk of obtaining dry holes and wells of variable production in the Venango district has always been greater than in the Bradford and Allegany. The oils are generally green, frequently black, and, in some instances, amber. The gravity varies from 30 to 51 degrees, 48 degrees being about the average gravity of the oil obtained from the third sand, which is the greatest producer. The Venango district, down to January, 1885, had produced about 55,000,000[1] barrels, an average of about 846,000 barrels per square mile.

[1] The Venango district, down to June, 1882, produced an aggregate of 53,569,000 barrels. Since that date, the reported production of this district has been included in that of the Butler and Beaver districts, so that the estimated aggregate product of the Venango, the Butler, and the Beaver districts, respectively, to 1885, is only approximate; although the total product of the three districts, composing what is now known as the Lower Field, has been obtained from actual reports. All the figures given in this paper, with one exception, have been based upon the statistics which have been published monthly in Stowell's 'Petroleum Reporter.' The aggregate production, to 1885, of the Beaver district, which has been compiled from various sources, is greater than that given either in the 'Petroleum Reporter,' or on the accompanying chart (Fig. 70), showing the annual production of the individual districts. Mr. Carll has prepared a 'Statistical Chart of the Oil Production in Pennsylvania and New York from 1859 to 1882,' which is published in the 'Survey Report on Warren County.' The statistics contained on Mr. Carll's chart have been collated by him from various sources, and I believe

5. The Butler district has been made to include the oil-pools in Butler and Clarion counties and southeastern Venango County. The total area of the oil-pools is 84 square miles, of which at least 76 square miles are embraced in the Clarion, Butler, and Armstrong field, and the Butler cross-belt. The oil in this district comes from the same group of oil-sands as in the Venango district. Certain splits occur in the sands, however, which have not been discovered in the Venango district. The character of the sands and the oils which they produce, vary much the same as in the Venango district, the individual oil or sand in one district having its counterpart in the other district. The Butler district, down to January, 1885, had produced about 69,000,000 barrels, an average of about 821,000 barrels per square mile.

6. The Beaver district includes the two principal oil-pools known as Slippery Rock and Smith's Ferry. The former pool, and that portion of the latter east of the Pennsylvania State-line, cover an area of about 16 square miles; the area of the Slippery Rock pool being about one-fourth that of the Pennsylvania portion of the Smith's Ferry pool. In both of these pools heavy oil is obtained from the representative of the Pottsville conglomerate, No. XII., and amber oil, from the Berea grit in the Sub-carboniferous series. The production of oil in this district down to January, 1885, was about 1,000,000 barrels, an average of 62,000 barrels per square mile.

Outside of the limits of these districts a small amount of oil has been found in isolated pools to the south and southeast of the Beaver and Butler districts; at Mt. Nebo, in the vicinity of Pittsburgh; in the vicinity of Pleasant Unity, Westmoreland County; near the mouth of Dunlap Creek, in Fayette County; along Whiteley Creek, west of Mapletown, and along Dunkard Creek, north of Fairview, both in Green County; and in the vicinity of Washington, in Washington County.

There is but little doubt, that the general boundaries of the oil regions of Pennsylvania are now well established; and it seems quite certain, that all the sands, in which oil will ever be found in paying quantities, are known and have been drilled through at different localities in the oil regions; so that we can have no reasonable expectation that any new and extensive field will be found, which could compare

them to be more accurate in detail than any which have ever been published. They differ but little in their general conclusions from those reported by Mr. S. H. Stowell, which latter have been much more convenient to use, in this connection.

in area or in the amount of oil to be obtained from it, with the Butler, Clarion, and Armstrong pool, the Oil City and Pleasantville pool, the great Bradford pool, or the Allegany pool. Prof. Lesley, in speaking of this subject, in January, 1883, says: "It is certain that petroleum is not now being produced in Devonian rocks by distillation or otherwise. What has been stored up can be got out. When the reservoirs are exhausted there will be an end of it. The discovery of a few more pools, of two or three million barrels each, can make little difference in the general result." Mr. Carll, in June of the same year, writes: "There are not at present any reasonable grounds for anticipating the discovery of new fields which will add enough to the declining products of the old, to enable the output to keep pace with the shipments or consumption." These results, foreshadowed by Prof. Lesley and Mr. Carll, were not generally appreciated until the latter part of 1883

The irregular, but, in the long run, steady decline, in the daily production of petroleum from July, 1882, when the maximum average daily production for any one month was attained (105,102 barrels) is now generally realized. The production for any one month, or any one year, may be increased very materially over what it is at present by renewed activity in drilling wells within the general confines of the oil region, or by working over old territory under the stimulation of a hungry market and high prices; but such an increase in production can only be of limited duration, since there is nothing to hope for, during a decade of years, but a progressive decline. In 1884, the total production of the region was 22,732,209 barrels, which[1] was nearly one million barrels less than the shipments; during the first eight months of the present year the production has fallen 2,022,355 barrels within the shipments. At the end of August, 1884, the maximum of stocks ever held in the oil regions was attained (39,084,561 barrels); two weeks ago (September 1, 1885), the stocks had declined to 35,343,771 barrels.

It is estimated that in July, 1883, there were, in the region, 17,100 producing wells, the average daily product of which was 3.8 barrels. In July, 1884, there were 21,844 producing wells, and the average daily product was 3 barrels; and, in July of this year, it is estimated

[1] The total production of 1884, as stated by the 'Petroleum Reporter,' was 24,772,209 barrels; the total production given above, like all the totals made use of in this paper, was computed from the individual monthly reports, and are believed to be correct.

that there were 22,524 producing wells having an average daily product of 2.5 barrels.

A defined territory, a product inadequate to meet the demand of the market for the past eighteen months, a growing market and rapidly diminishing stocks, an increasing number of drilling and producing wells, and a rapidly-falling average daily product per well, are all significant signs of a certain decline in a great industry; and yet the average price of crude oil per barrel for the month of July, 1885 (92½ cents), was 13¼ cents less than the average price for the entire year of 1883, and only 9 cents more than the average price for 1884. In the month of August, 1885, the average price per barrel had risen to \$1.00¼. Although this is a great advance over the price for the preceding months of the year (January, \$0.70⅞, February, \$0.72⅜, March, \$0.80⅜, April, \$0.78½, May, \$0.79, June, \$0.82), yet, in view of the conditions of the petroleum industry above referred to, it is not as great as might reasonably be expected.

At the Washington meeting of the Institute, held in February, 1882, the late Henry E. Wrigley read a paper on the amount of oil remaining in Pennsylvania and New York (*Transactions* X, 354), in which he gave the area of the oil-territory, the amount of oil produced per square mile, and estimates of the amount of territory yet to be drilled over, and of the quantity of oil which could be expected. I do not wish to make special criticism of Mr. Wrigley's statements or conclusions, but merely to say that facts did not sustain his statements, and I never accepted his conclusions. The mystery, with which the operations in the oil-regions have been conducted during the last ten years, makes it extremely difficult to gather authentic particulars from the drillers or producers; and, were it not for the valuable service which Mr. Carll has rendered, as far as the records of oil wells and the geology of the region are concerned, and that which has been rendered by Mr. Stowell, in the collation and publication of statistics, it would be impossible, even now, to arrive at any conclusions bearing on the questions to which I have presumed to make brief reference in this paper.

The geologists of the Pennsylvania Survey, and a few of the oil-operators who have given the subject a careful consideration, are united in believing that the general confines of the territory are defined, and it is admitted that it is in vain to drill wells, as has been done during the past year, in Lycoming and Chester counties, where none of the conditions, under which oil has been obtained in

Pennsylvania, are to be found. The fact must not be lost sight of, however, that some of the individual oil-sands have been explored within limited areas only of the oil-region proper. For instance, the Bradford sand, which has been found so prolific in the Allegany and Bradford districts over an extent of territory 42 miles in length, and in places 15 miles in breadth, owing to its great depth below the surface, and the procurement of oil at higher horizons, has not been thoroughly explored in districts to the southwest, although this is the producing sand in the Cooper pool, and in several instances wells have pierced its horizon.

In February, 1878, in a paper which I read before the Engineers' Club of Philadelphia, on the oil-sands of Pennsylvania, I referred to the discovery of the Smethport oil-sand in McKean County, about 360 feet below the bottom of the Bradford oil-sand. What the possibilities of obtaining oil at this horizon anywhere in the oil-region are, it is impossible at present to state. The horizon of this sand has been pierced by several wells, and a small show of oil has been found; but additional wells drilled for exploring this sand may prove complete failures. It is a noted fact that no two oil-sands, one immediately above the other, have been great producers over the same extended area. I have called attention to these facts, as those which may influence the extent of the production of oil in Pennsylvania and New York in the future.

In 1882, Mr. Wrigley stated that the total production to the commencement of that year had been 154,000,000 barrels, and that only 96,000,000 barrels of oil remained to be got. Down to the commencement of the present year, the total product of the oil-regions was 261,000,000 barrels, as shown by the accompanying chart. That the product has passed its meridian there is no question, but what the total aggregate for the future will be it would be folly to attempt to estimate. That the product per well will be less, and the cost of producing one barrel much more, than in the past, experience would seem to prove. These, with other collateral facts connected with the production, manufacture, and consumption of the product, will make the exhaustion of the field a gradual one; and, it is probable, that long before every barrel of oil shall have been taken out of the oil-sands the cost of production per barrel will be so great, that the oil-men's occupation in Pennsylvania and New York will be gone. It is hardly probable that the Japanese practice of excavating a vertical shaft 600 feet in depth to obtain a few gallons of oil a day will ever prove a profitable enterprise in America.

THE GEOLOGY OF NATURAL GAS.

BRIEFLY STATED BY

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The earliest historical records contain references to the occurrence of natural gas. The Magi of Asia at least six hundred years B. C. were worshippers of the *external fires* which blazed in fissures in the mountains in the vicinity of the Caspian Sea, subsequently the adherents of the Parsee sect founded by Zoroaster when they subjugated the tribes surrounding the Caspian adopted the fire-worship of the conquered.

The Chinese in the district Tsien Luon Tsing have been using natural gas for centuries, getting the gas from wells reported to be three thousand feet deep, conveying the same in bamboo pipes and burning it with clay burners.

The "*Fontaine Ardente*" of the Gauls in the vicinity of Grenoble, France, was burning in the time of Julius Cæsar.

In America, the early Jesuit Fathers record in their writings the existence of burning springs. In 1775, it is said that Washington, during a visit to the Kanawha Valley, Virginia, set apart a square mile of land above Salt Lick, upon which was located a gas spring. This land he deeded to the public, but an informality in the deed, subsequently discovered, rendered the conveyance void.

The existence of natural gas-springs in Pennsylvania and the adjoining States west of the crest of the Allegheny Mountains was known to the earliest settlers. Possibly the first gas obtained from a well was at Fredonia, Chautauqua County, N. Y. Here a well, in 1821, on the bank of Canadaway Creek, near the Main Street bridge, was sunk, and sufficient gas was obtained for 30 burners, the inn having been illuminated by the gas when General Lafayette passed through the village about 1824. In 1858 another well was drilled, which supplied about 200 burners. A still larger well was drilled to a depth of 1200 feet in 1871. According to Mr. E. J. Crissey,

Secretary of the Fredonia Natural Gas Light Company, the average monthly supply of these wells in 1880 was 110,000 cubic feet.

Since 1859, when the drilling of oil wells in Western Pennsylvania was commenced, natural gas has been obtained either in conjunction with oil or in wells which produced only a trace of oil. In most of the flowing oil-wells, the pressure which forces the oil up the well results from the gas contained in the oil sand in the immediate vicinity of the well, or at a considerable distance away. In the former case, gas is frequently mixed up with the oil as it intermittingly flows from the well-mouth, the gas coming from the well continuously between the oil-flows; while in the latter case, no perceptible quantity of gas is obtained from the well. I believe that, by special examination, all the oil coming from the Pennsylvania and New York wells may be proved to contain *some* gas.

The product of gas-wells has been utilized in various ways, particularly for light and fuel at the towns and villages in the immediate vicinity of the wells, and also, to a limited extent, for the manufacture of lampblack—sometimes called "diamond black"—by the deposition of the carbon resulting from the imperfect combustion of the gas; but a comparatively small proportion of all the gas produced in the region, however, was ever made use of until within the last two years, when the introduction of gas into the industrial establishments—principally iron, steel, and glass works—in the vicinity of Pittsburgh have made its use as a fuel an important consideration in the manufacturing industries of Western Pennsylvania.[1]

[1] It is estimated that at present (August, 1885), in the city of Pittsburgh alone there are being supplied with natural gas 1500 dwellings, 66 glass factories, 34 rolling mills, and 45 other industrial establishments, and that about 10,000 tons of coal are thereby displaced daily. The gas consumed in Pittsburgh is used almost exclusively for fuel. The following figures, reported by T. P. Roberts, show the estimated value of coal supplanted by natural gas consumed in Pennsylvania, New York, Ohio, and West Virginia, in 1882, 1883, 1884, and 1885:—

1882	Pittsburgh region,	$ 75,000.	Elsewhere,	$140,000.	Total,	$ 215,000.
1883	"	200,000.	"	275,000.	"	475,000.
1884	"	1,100,000.	"	360,000.	"	1,460,000.
1885	"	and	"		"	4,854,200.

In November, 1886, the Philadelphia Company, the largest natural gas company in Pittsburgh, was distributing about 200,000,000 cubic feet of gas daily to 400 mills and 7000 domestic consumers. The progress made in the gas business from August, 1885, to November, 1886, has been marvellous.

The extensive drilling which is now being done by manufacturers, gas companies, and property owners in all sections of Western Pennsylvania and contiguous areas in adjoining States, where it is thought natural gas may be obtained, has made the study of the geology of natural gas one of pressing importance as an aid in the location of profitable wells.[1]

The general conditions upon which the occurrence of natural gas seems to depend, from a consideration of the facts at present at our command, are: (*a*) the porosity and homogeneousness of the sandstone which serves as a reservoir to hold the gas; (*b*) the extent to which the strata above or below the gas-sand are cracked; (*c*) the dip of the gas-sand and the position of the anticlines and synclines; (*d*) the relative proportion of water, oil, and gas contained in the gas-sand; and (*e*) the pressure under which the gas exists before being tapped by wells. Other conditions may still be discovered which will have as important a bearing upon the problem as these which I have stated.

The oil and gas regions of Pennsylvania are one in a geological sense.

The existence of natural gas, either in or near all the productive oil-pools, under geological and physical conditions similar to those found to obtain in what are frequently spoken of as "natural gas-regions proper," are all sufficient reasons for considering the districts, containing wells which are supposed to produce either oil or gas exclusively, one geologically. This conclusion is an important one in the consideration of the geology of natural gas, and it is believed that it is fully borne out by the numerous columnar sections of strata in Western Pennsylvania which have been published by the Geological Survey.

The general structural geology of the oil- and gas-regions is comparatively simple. The rocks lie nearly horizontal, being thrown into broad and almost imperceptible rolls by southwest-dipping anticlines and synclines which are parallel, in a general way, to the escarpment of the Allegheny Mountains, and which produce gentle northwest and southeast dips from the crests of the anticlines down toward the centres of the synclines. An appreciation of the intensity of these dips may be had from the following figures: From the city of Brad-

[1] I believe it to be possible for an *experienced practical* geologist to define areas where it is impossible to obtain natural gas, and, therefore, where it would be the height of folly to drill wells, and other areas where it is possible for natural gas to exist.

ford, in McKean County, immediately south of the Pennsylvania and New York State line, and about 72 miles, in an air-line, a little south of east of the city of Erie, the strata dip at an average rate of 14 feet per mile to Oil City, which is 64 miles south 55° west of Bradford. From Oil City to Pittsburgh, a distance of 70 miles in a direction south 12° west, the average rate of dip per mile is about 20 feet. From the city of Erie to Beaver, on the Ohio River, at the mouth of the Shenango River, the distance is about 100 miles in a direction south 7° west, and the average rate of the fall of the strata is 20 feet per mile. Although these are the general dips of the rocks, yet many very much greater local dips occur in the areas between the localities named. The maximum dip in the Bradford oil-region, which I determined from my surveys in 1879, was 69 feet per mile, and this for a distance of only 2½ miles. In the Venango oil-belt and southern end of the Butler oil-belt the dip of the oil-sands, as shown by Mr. Carll's survey, rarely exceeds 35 feet per mile. A dip in the strata at the rate of 75 to 100 feet per mile, for even very short distances, is the rarest occurrence.

Although the horizontal structure of the oil- and gas-regions is comparatively simple, the columnar structure, as revealed both by the study of the outcropping rocks and the records and drillings of oil-wells, is not so easily understood, and in special areas is more or less complex. The rocks which have so far been found to produce natural gas are found in a vertical range of about 3000 feet of Carboniferous and Devonian strata, extending from the Mahoning sandstone at the base of the Lower Barren Coal measures, which is on an average about 500 feet below the Pittsburgh coal-bed, down to the Roy and Archer gas-sand in Elk County, which is about 500 feet below the great Bradford oil-sand of that region. The principal gas-horizons are, (*a*) the probable representative of the Venango first oil-sand at Pittsburgh, which is from 1800 to 1850 feet below the Pittsburgh coal bed, and contained, as I believe, in the Catskill formation No. IX.; (*b*) the Sheffield gas-sand, which appears to be the lowest oil- and gas-sand in Warren County—the horizon of this sand is about 800 feet above the bottom of the interval of 3000 feet; (*c*) the Bradford oil-sand, which occurs 1775 feet below the base of the Pottsville conglomerate, which is the lowest member of the Lower Productive Coal measures; and (*d*) the Roy and Archer gas-sand which occurs about 500 feet below the Bradford sand south of Kane. The Sheffield, Bradford, and Roy and Archer sands are undoubtedly of Chemung age.

While most of the largest gas-wells which have been drilled in Pennsylvania have obtained gas from these four horizons, yet gas in commercial quantities is not exclusively confined to them. Between the Mahoning sandstone as the top limit and the Roy and Archer gas-sand as the bottom limit, about 10 (more or less) prominent sand-beds have been found which produce petroleum, and each one of these sand-beds has been found to contain gas in greater or less quantity, nor is it possible to say that the gas is confined exclusively to these definite sand-horizons, for sand-beds having only a local occurrence, but included within the rock interval of 3000 feet, may contain gas.[1]

The origin of natural gas has an important bearing upon its economic geology. Although it is believed that we are in possession of much data to throw some light upon this interesting question of cause, yet it is still shrouded in too much uncertainty to permit of complete explanation. It is necessary, however, that some statement should be made in regard to the origin of gas in order to thoroughly comprehend the conditions upon which its existence seems to depend. It would appear that the gas is closely related to petroleum,[2] and

[1] Outside of Pennsylvania, in West Virginia, Ohio, and Kentucky natural gas is not confined to the Devonian formation, but has been obtained from strata as low in the geological column as the Lower Silurian limestone, although the most productive wells have obtained the gas from the Pennsylvania Devonian sands.

[2] According to Prof. S. P. Sadtler, the Pennsylvania and New York petroleum is a mixture of hydro-carbons, which can be classed under the marsh-gas series (paraffines), having a general formula $C_nH_{2n}+_2$, and the ethylene series (olefines) having a general formula C_nH_{2n}. The composition of natural gas from different wells, or from the same well at different times, is found to vary slightly; according to recent analyses made by Mr. S. A. Ford, the average composition of the gas in the vicinity of Pittsburgh is—

	Per cent.
Carbonic acid	.6
Carbonic oxide	.6
Oxygen	8
Olefiant gas	1.0
Ethylic hydride	5.0
Marsh gas	67 0
Hydrogen	22.0
Nitrogen	3.0
	100.0

100 litres weigh 64.8585 grams: 1000 cubic feet natural gas is equivalent in heating power to about 55 pounds of the average Pittsburgh bituminous coal.

that their origin is due largely to the same cause—the decomposition of animal and vegetable remains. It is believed that the gas is not entirely indigenous to the sand-rock from which it is obtained, but comes largely from the decomposition of life-forms which were entrapped in underlying strata. If this be so, the amount of gas contained in any one sand depends, first, upon the extent to which the rocks are cracked between the horizons of such organic remains and the gas-sand reservoir, in order to permit the gas to flow into the sand; and, second, upon the extent to which the rocks are cracked above the gas-sand, which would permit the gas to escape into the atmosphere and totally disappear.

That the absence of both petroleum and natural gas in our plicated strata east of the oil regions is to be explained by the cracking of the rocks would seem to be evident, since the survey of the outcropping rocks and a study of the records of dry wells, show that the oil- and gas-sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil- and gas-wells have been found, the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities.

The first necessary condition for the presence of gas, however, is dependent upon the existence of a porous rock to serve as a reservoir to hold it. A number of wells have been drilled which have found gas, but, if the drillers' records are to be credited, have not pierced sand-beds; in these cases the gas has been unquestionably obtained from a crack in the strata which serves as a conduit to convey the gas from its sand-bed reservoir to the well. Although the dip of the gas-sand and position of the anticlines and synclines have an important bearing upon the occurrence of gas (in many cases this would seem to be the most important consideration), yet it is not believed that natural gas-wells can be located on what has been formulated as "the anticlinal theory," since all great gas-wells are not found along anticlinal axes, although some of the largest and most important wells in Pennsylvania have been found in such positions. A great many wells have been drilled in synclines which have found gas. These two statements are of great importance, since a large amount of money is now being expended in drilling wells which have been located on the basis of the so called anticlinal theory.

The relative proportions of water, oil, and gas in a sand-bed, and

the pressure[1] under which the gas exists, have an important bearing upon its occurrence, when considered in conjunction with the dip of the sand and the position of anticlines. If nothing but gas existed in a given homogeneous sand-bed, having only the ordinary dip of the strata of the oil-region, from which the gas could not escape by cracks into overlying strata, and the quantity of confined gas were such that it should fill all portions of the rock with gas under a great pressure, it must be apparent that, no matter where the gas-sand was pierced by a well, the same quantity of gas would be obtained, excepting so far as it might be influenced by the force of gravity. If petroleum, water, and gas should all exist in the same sand-bed, the pressure on each would necessarily be approximately the same, if there was an open connection throughout the whole extent of the rock in which they occurred; but the water would seek the lowest level of the sand-bed, the oil the next, and the gas would be found in the highest portions. The same condition of affairs would exist where either water or oil existed in the sand with the gas to the exclusion of the other.

A careful study of these facts makes it apparent, that, under special conditions, the anticlinal theory alone may account for the existence of gas; but when, however, it is known that large gas-wells have been found in synclines, under conditions differing from those which obtain in the vicinity of gas-wells on anticlines, it is quite certain that the occurrence of natural gas in the Pennsylvania and New York regions can be explained only by a careful consideration of *all* the geological and physical conditions under which it is procured.

It is difficult to prescribe any fixed limits in the geological scale to the occurrence of natural gas and petroleum[2] throughout the United States. Every known rock, except the eruptive rocks, contains the remains of organisms, animal and vegetable; and, since it is quite certain that both oil and gas result from the decomposition of organic remains, it is quite possible to find oil and gas in rocks of any geological age, subsequent to the Archæan, or rocks without life: in some rocks in commercial quantities, and in other rocks in quantities

[1] Pressure as high as 900 pounds to the square inch have been measured at several wells; a pressure of 400 to 500 pounds, however, is considered high.

[2] All petroleum-bearing rocks contain gas in greater or less quantity, and in all rocks holding gas a certain amount of petroleum, however small, is sure to be found.

so small as to be only of scientific interest to the geologist and mineralogist.

Next to the necessity of having a sedimentary bed, such as sandstone, shale, or slate, in which animal or vegetable remains of past geological ages have been buried, or a limestone bed made from water shells, the presence of natural gas is dependent upon the existence of a porous or cavernous rock to serve as a reservoir to hold the gas, and of an overlying impervious rock-roof to confine the gas. The other necessary conditions for the occurrence of gas are more dependent upon the forces to which the strata have been subjected and the resulting geological structure, than upon the age of the rocks themselves.

The practical necessity of gas-explorers first understanding the structure of the rocks in any locality where explorations are planned, is tersely set forth in the following, from a few of the conditions recently enumerated by Professor Lesley, as to the occurrence of gas in Pennsylvania:—

"Shall I bore for gas at my works? is a question so often asked and so seldom answered with intelligence, that a short statement of the principles involved in a correct answer to it will probably be of use.

"First of all, there can be no gas stored up in the oldest rocks.

"Secondly, there can be no gas left underground, where the old rocks have been turned up on edge and overturned, fractured and re-cemented, faulted and disturbed in a thousand ways. If there ever was any, it has long since found innumerable ways of escape into the atmosphere.

"Thirdly, there is not the least chance that any gas is left under ground in the greatly folded, faulted, crushed, and hardened formations. Where the oil and gas-rocks rise to the surface as they do in a thousand places, they show that all their oil and gas has escaped long ago.

"Where the rock-formations lie pretty flat and have remained nearly undisturbed over extensive areas, there is always a chance of finding gas (if not oil) at some depth beneath the surface determined by the particular formation which appears at the surface.

"And, finally, wherever rock-oil has been found, there and in the surrounding region rock-gas is sure to exist."

The question of the geological structure of the rocks in possible

oil and gas territory is of great importance in practical explorations as the question of the geological age of the rocks themselves.

Although petroleum and gas have both been reported as existing in a majority of the States, and occurring in geological formations from the glacial drift of the Quarternary system, down to the Trenton limestone at the base of the Palæozoic system, yet at present our prominent producing gas-districts are confined to New York, Pennsylvania and Ohio; and the gas comes from the Palæozoic strata. In a number of other States, the oil and gas shows are sufficient to warrant a practical exploration for natural gas.

The tendency among practical oil- and gas-well drillers and operators to discover in a new district the same section of rocks as found in an old district, however distant the new district may be from the old, makes it important that both drillers and operators should realize the fact, as proven by geological investigation, that no two wells can be put down, distant from one another but a few miles, where the same section rocks can be found in both wells.

Many illustrations might be cited to prove this assertion. One which has come to my notice within the last few weeks, may, however, make this point clear: Two wells exploring for gas were located without the aid of a professional geologist in a certain district, and drilled by as intelligent operators and drillers as one will find in a day's travel in the Pennsylvania region. One of these wells was started in the Hudson River slates and drilled to the Trenton limestone, with the hope of finding gas. The other well, about twenty miles distant from the first, was started in the Catskill sandstone, and it was expected that the Trenton limestone would be found at the same depth in this well as in the first well. When my advice was subsequently sought I was able to prove, after an extended survey, that the stratum in which the first well was started could not be reached in the second well before the drill should have gone to a distance of one vertical mile, a depth 600 feet[1] greater than has ever been drilled to on the American continent.

All the oil and gas in the three States referred to have been found in the sandstone, shale, and limestone strata of the Palæozoic system,

[1] The Dilworth well, being drilled by Mr. George Westinghouse, Jr., at Homewood, Allegheny County, Pennsylvania, had attained a depth of 4618 feet, December 1, 1886, and is still being drilled deeper. This is the deepest bore-hole which has been drilled on the continent. The last report I have of the Sperenberg well near Berlin, gives the depth as 517? feet.

with the exception of a small amount of gas, which has been found in the glacial drift in Ohio and New York. The thickness of these strata ranges from 5000 feet in Ohio, to 30,000 feet in Central Pennsylvania, to 11,000 feet in Eastern New York. On account of the varying thickness of the rocks, it is readily perceived that a knowledge of the different individual formations in special localities where gas-explorations are to be carried on, is of the highest importance.

It has been a fact long recognized by geologists, that, in some cases, many of the exploration- or "wild-cat" wells are drilled through formations in which it is highly improbable that any gas will be found; that in other cases, the wells have been drilled to a greater depth than would be necessary to make the test complete, thereby incurring needless expenditure; and that, in still other cases, wells have not been drilled deep enough to make the test as to the existence of gas a satisfactory and final one.

The amount of gas at present flowing from the explored sands in Pennsylvania is probably two or three times greater than is required to meet all present demands. With an appreciation of this fact, and of the possibility of extending the gas-pools and developing new ones, very little alarm should be entertained as to the exhaustion in the near future[1] of the gas-sands of Pennsylvania and the prostration of the manufacturing interests which have now become dependent upon its use.[2]

[1] It must be remembered that there seems to be no doubt that all the gas which can be obtained for commercial purposes now exists, and is stored in an exhaustible reservoir; so that, the same as with all other mineral deposits, the life of a gas-pool is proportional to the amount of gas contained and to the demands made upon it.

[2] There is no ground for the alarm which is entertained by some persons in the gas-regions, but by many more in other sections of the country in the direction indicated, since some of the natural gas supply-companies (notably, the Philadelphia Company) have already taken into consideration the manufacture of a fuel-gas which, in the event of the failure of the natural product, could be supplied to consumers, even in the Pittsburgh coal-region, at prices which would compete with the cost of coal. A company is now being organized in Pittsburgh, for the purpose of organizing heat, power, and light companies throughout the United States. This company has planned to introduce natural gas wherever it can be found for fuel in conjunction with electricity (Westinghouse Incandescent System) for light. Where natural gas cannot be found, it is planned to combine with existing illuminating-gas companies, convert the illuminating-gas plant into a fuel-gas plant, and replace the illuminating gas by electricity.

It becomes a question of vital importance to the Commonwealth of Pennsylvania, and to every citizen interested in the industrial concerns of the State, that the extravagant waste of natural gas, now going on everywhere throughout the oil- and gas-region should be stopped. The action of the Philadelphia Company, which is now the largest natural-gas company in Pennsylvania, in shutting in the wells all the surplus gas which is not needed, should be emulated by every individual who has pecuniary interest in gas-wells; and it is a question which should be settled by our State Legislature, by compelling all gas-well drillers and operators to shut in the gas which is not needed.

Although I believe the present manufacturing and domestic consumers of natural gas will not return to coal for fuel when the gas is exhausted, but will use a manufactured fuel-gas, yet at the same time, a region such as Pittsburgh, where natural gas is so abundant, must always have an advantage over a community depending upon manufactured fuel gas; and as long as the Pittsburgh supply of gas can be kept up, it will induce manufacturers to establish their works at Pittsburgh in preference to other places, and thus add to the wealth of the State. For this reason it behooves every citizen of the State whether in Pittsburgh, in Philadelphia (where natural gas will never be found), or elsewhere, to prevent the criminal waste of gas which is now going on in so many localities in Western Pennsylvania.

In Ohio, as far as developed, all the natural gas horizons are contained in Palæozoic strata, from the Upper Coal-Measures down and into the Trenton limestone. The most prolific gas-bearing rocks are the Berea grit in the Sub-carboniferous Period, and the Trenton limestone in the lower Silurian Period.

Professor Orton calls the territory in which gas is obtained in the Berea grit and Trenton limestone high-pressure territory, and the territory in which the gas comes from the Ohio, Clinton, Medina, and Hudson River shales, low-pressure territory.

The discovery of natural gas in Ohio, *if the deposits are sufficiently great and constant in their supply for commercial purposes*, is the dawn of a most important era for the manufacturing and industrial interests of that State. One circumstance is worthy of special mention in this connection. In Pennsylvania, the finding of natural gas has been confined largely to the region in which valuable coals were already being mined and were supplying a cheap and desirable fuel

to established manufacturers. In Pennsylvania, again, the finding of natural gas will, probably, be always confined to regions producing coal, or regions but a few miles removed from coal-mines, and in which coal can be commanded almost as cheaply as in those gas localities immediately at the coal-mines. But in Ohio, gas has been found in areas which do not produce as good a coal for manufacturing purposes as in Pennsylvania, and in other areas, many miles removed from any coal-field.

Any comparison as to the amount of gas which Pennsylvania and Ohio respectively will be able to produce in the future, would be invidious, and in fact we have not sufficient evidence upon which to base any reliable conclusion. That there is sufficient gas in Ohio, as well as in Pennsylvania, to meet the demands of manufacturers for a number of years, and sufficient in many localities to warrant the erection of new plants there is no doubt; but still it is well to bear in mind that our gas-supply is exhaustible, and that our future supply is now stored in buried rock-reservoirs. When these reservoirs are emptied our supply will have gone.

The literature on the subject of the geological occurrence of natural gas, except in areas contiguous to the Pennsylvania oil-regions, is very meagre; and scarcely anything has been published on its geology, except that contained in the reports of the Pennsylvania Survey, in a pamphlet report recently published by Dr. Orton, State Geologist of Ohio, and in special private communications by Mr. Carll, Dr. Chance, Prof. White, and myself.

RUSSIAN PETROLEUM.

SINCE the chapter on this subject in this volume was printed, the announcement is received in this country of a new and "the greatest outburst of oil ever known."

Mr. Charles Marvin, writing to the 'Pall Mall Gazette' (London), says:—

"The Russian newspapers just received contain a telegram from Baku, announcing the greatest outburst of oil ever known. It runs thus: 'Baku, October 5.—At Tagieff's wells a fountain has commenced playing at the rate of 30,000 pouds of petroleum an hour. Its height is 224 feet. In spite of its being five versts from the town the petroleum sand is pouring upon the buildings and streets.' It is astonishing that the St. Petersburg correspondents of the London papers should not have telegraphed this remarkable phenomenon, and I can only account for their remissness on the grounds that they have either been too pre-occupied with Bulgarian matters, or have grown so accustomed to fresh oil fountains at Bakù, lately, as to be blunted to the significance of the present one. Yet Tagieff's 'gusher' beats, out-and-out, every previous record in the oil-regions of the two hemispheres. The champion petroleum fountain up to now has been the 'Droojba,' which in 1883 spouted to the height of 200 feet or 300 feet, at the rate of nearly 3300 tons of oil a day. 'This single well,' I wrote from the spot in that year, 'is spouting more oil than all the 25,000 wells in America yield together.'

"Such an outflow was looked upon as almost incredible, and had there not been other Englishmen at Baku at the time, I should have probably fared as badly as Bruce and other travellers. But the Droojba is now nowhere. Tagieff's well is spouting nearly 500 tons an hour, or more than 11,000 tons of oil a day. If it were in London it would top the Monument by 20 feet, and the mansions of far-off Belgravia would be covered with its greasy dust. During the birth throes of a Baku oil fountain stones are hurled a terrific distance, and a high wind will carry the fine sand, spouting up with the oil, miles away. The roar of the gas preceding the oil-flow is terrific,

and the atmosphere for a time is rendered almost unbearable. Compared with such fountains as the Droojba and Tagieff, the Great Geyser of Iceland is a pigmy. Luckily the gas soon clears off, the stones cease to rattle about the surrounding buildings, and then the fountain becomes as orderly as those in Trafalgar Square, pouring upwards sky high with a prodigious roar and forming round about the 13-inch or 14-inch orifice vast shoals of sand, beyond which the petroleum gathers in lakes large enough sometimes to sail a yacht in.

"How long Tagieff's 'spouter' will last, and what its ultimate yield will be, will depend upon circumstances. The Droojba lasted 115 days, flowing for 43 days at the average rate of nearly 3400 tons a day, 31 days at 1600 tons, 30 days at about 900 tons, and 11 days at 600 tons. The owners then managed to fix a 'cap' over the orifice, and placed the well under control. The total amount of oil spouted, at the very lowest estimate, was 220,000 tons, or 55,000,000 gallons; the highest estimate put it at 500,000 tons. At a rough estimate, had the oil spouted in America, it would have realized about a million sterling, and made its owner a millionaire, instead of which the fate of the fountain at Baku was to render its master a bankrupt; for the shoals of sand engulfing neighboring buildings led to claims of damage surpassing what he got for the small quantity of oil he was able to catch and store, while the rest, flowing beyond on to other people's property, was in most cases 'annexed' and not paid for. It is to be hoped that Tagieff & Co. will not be so unlucky; but in any case most of it is sure to be wasted."

Mr. Marvin has just published in London a pamphlet bearing the significant title 'The Coming Deluge of Russian Petroleum,' in which he calls attention to the fact that this industry is now attracting the attention of every country in Europe but his own, and arrives at the conclusion that unless England displays immediate promptness and energy the petroleum trade of not merely Baku, but of the world, will slip through her fingers. While England has constructed but two or three tank steamers, the Swedes, he says, have built nearly one hundred for the Volga and Caspian alone.

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